Groundwater Monitoring Plan

Greif Packaging LLC - Industrial Landfill
Permit No. 536

DAA Project No. 22299-174

Prepared For:
Greif Packaging LLC
Riverville, Virginia

Submitted To:
Virginia Department of Environmental Quality
Blue Ridge Regional Office
Salem, Virginia

November, 2020
Revised July, 2021

Draper Aden Associates
Engineering • Surveying • Environmental Services

GREIF PACKAGING LLC
GREIF PACKAGING INDUSTRIAL LANDFILL
RIVERVILLE, VIRGINIA

GROUNDWATER MONITORING PLAN

DEQ PERMIT NO. 536
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1.0 SUMMARY

The subject Groundwater Monitoring Plan was developed for the Greif Packaging LLC Industrial Landfill (formerly Virginia Fibre Industrial Landfill) in accordance with applicable sections of the *Virginia Solid Waste Management Regulations (VSWMR)*.

The Plan represents the controlling document for obtaining and analyzing representative groundwater samples from the uppermost aquifer underlying the facility.

The subject Groundwater Monitoring Plan (GWMP) supersedes the following previously prepared Groundwater Monitoring Plans:

- GWMP prepared by Draper Aden Associates (November 2003; revised January 2004, per *VSWMR Amendment 3*) - DEQ approved on March 30, 2004
- GWMP prepared by Draper Aden Associates (May 2010; revised November 2010)
- GWMP prepared by Draper Aden Associates (October 2013)

2.0 FACILITY INFORMATION

Permit no:	536
Name:	Greif Packaging LLC industrial landfill
Owner/operator:	Greif Packaging LLC [formerly Virginia Fibre Corp., Greif Bros. Inc.]
Location:	southwest of Riverville, Virginia, on State Route 823, Amherst County
Class:	solid waste facility
Type:	industrial landfill
Liner:	lined
Disposal Method:	area fill
Leachate:	collection system installed
Acreage:	45 acres, 19.3 acres designated for waste disposal
Water bodies:	James River - located approximately 0.75 mile southeast of landfill
Wetlands:	wetlands inventory map - Part A Application (March 1989)
Adjoining land use:	permitted landfill is surrounded by industrial property that is also owned by Greif Packaging; industrial use to the southeast, industrial but not developed (mostly forested) on all other sides of the landfill; two potable water supply wells are located on property adjoining the landfill and owned by Greif Packaging several sparsely distributed residential structures are located to the north, northwest, west, and southwest of the large Greif Packaging tract; all residences are presumed to have private water supply wells; all residences are believed to be either hydrogeologically upgradient of, or hydrogeologically separated from, the landfill
Facility Status:	active - receiving waste since 1992
Groundwater status:	Phase II Monitoring [March 2009] Groundwater Protection Standards approved November 1, 2010

3.0 DEFINITIONS

The following definitions are applied in this document:

Limit-of-Detection (LOD)[1]. The Limit-of-Detection is the lowest concentration that can be determined to be statistically different from a blank and is numerically defined as 3.14 (with six degrees of freedom) times the standard deviation of seven replicate measurements. The LOD must be determined for each parameter and is specific to the individual laboratory.

Limit-of-Quantitation (LOQ). The Limit-of-Quantitation is the level above which quantitative results may be obtained with a specified degree of confidence and is numerically defined as 10 times the standard deviation of seven replicate measurements (or 3.18 times the LOD as calculated above). The LOQ must be determined for each parameter and is specific to the individual laboratory.

Method Detection Limit (MDL). The Method Detection Limit is the minimum concentration of a substance that can be identified, measured, and reported with 99 percent confidence that the concentration of the parameter is greater than zero. The MDL is determined from analysis of a sample in reagent water containing the parameter. Whereas each laboratory determines its own LODs, MDLs represent published information.

Estimated Quantification Limit (EQL). The Estimated Quantification Limit is an inter-laboratory concept and is numerically estimated at 5 to 10 times the Method Detection Limit. The EQL is derived from laboratory performance, under ideal circumstances, of selected laboratories (not all laboratories). EQLs provide performance goals. Whereas each laboratory determines its own LOQs, EQLs represent published information.

Facility background concentration (FBAC). The facility background concentration represents the largest concentration of a constituent that may be observed in any downgradient well that will not trigger Assessment Monitoring. If a given constituent has been observed frequently among upgradient wells, then facility background may be represented by a statistical prediction limit (SPL). If a given constituent has not been observed among upgradient wells (or observed only rarely), facility background may be represented by one of several possible analytical limits of quantitation.

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1 The definitions for LOD, LOQ, MDL and PQL (EQL) have been extracted from Cochran, R.A. and D.L. Lanzola, 1993. *Data quality crucial to laboratory work*. Environmental Protection. p. 16.

Laboratory reporting limit (QL). The laboratory reporting limit is the minimum concentration that a given laboratory presents on its certificate-of-analysis. Each laboratory determines its laboratory reporting limit.

Statistical prediction limit (SPL). A statistical prediction limit represents the largest concentration that is likely to be observed among upgradient wells at a specified probability. Statistical prediction limits may be calculated using a variety of techniques, depending upon the distributional nature of the data.

Maximum Contamination Level (MCL). The MCL is the EPA Drinking Water Standard and is subject to change as promulgated by the EPA.

Groundwater Protection Standards (GWPS). A Groundwater Protection Standard represents the largest concentration of a constituent that may be observed in any downgradient well that will not trigger Corrective Action.

Alternate concentration limit (ACL). The Director of the DEQ may establish a risk-based alternate concentration limit for constituents that are not associated with an MCL. Alternate concentration limits for some Appendix 5.1 constituents have been developed by the DEQ, and are subject to change without notice. Alternate concentration limits may also be developed by others by considering health effects of exposure, subject to approval by the Director.

Point of compliance (POC). The *point of compliance* is the place in the uppermost aquifer where groundwater monitoring takes place and the Groundwater Protection Standard is set. The *point of compliance* must be within the facility boundary and shall not be more than 500 feet downgradient from the waste management boundary.

Point of exposure (POE). The *point of exposure* is the point at which risk is evaluated. The *point of exposure* is often considered to be either (1) the property boundary or (2) nearest point of groundwater discharge (whichever is closer to the waste management unit boundary).

4.0 DESIGN OF THE GROUNDWATER MONITORING NETWORK

Components of the groundwater monitoring network are summarized below and illustrated on FIGURE 5 (APPENDIX 1). Specifications for existing and future wells are presented in APPENDIX 4.

4.1 Permitted Well Network

The permitted monitoring well network at the Greif Packaging Industrial Landfill shall consist of seven wells: MW-01, MW-05, MW-06, MW-07, MW-08, MWB-01, B-12 (APPENDIX 1).

Background wells. Data derived from three monitoring wells will be pooled in order to establish facility background water quality conditions:

- Monitoring well ***MW-01*** is located *upgradient* from all solid waste management units. Well MW-01 is screened within residual soils in the uppermost aquifer underlying the facility.
- Monitoring well ***B-12*** is located *upgradient* from all solid waste management units. Well B-12 is screened within the residual soils in the uppermost aquifer underlying the facility.
- Monitoring well ***MWB-01*** is located to the east (*cross-gradient*) of the industrial landfill, and previously served as the upgradient well at the closed "bark landfill." Well MWB-01 is screened within the residual soils in the uppermost aquifer underlying the facility.

Downgradient points-of-compliance. Monitoring wells ***MW-05***, ***MW-06***, ***MW-07,*** and ***MW-08*** are *downgradient* from solid waste management units and shall serve as regulatory points-of-compliance. Wells MW-05, MW-06, MW-07, and MW-08 are screened within residual soils in the uppermost aquifer underlying the facility.

In order to ensure consistency in monitoring the uppermost aquifer underlying the facility, as required by *VSWMR*, all background and point-of-compliance wells are screened within residual soils overlying metamorphic bedrock. Future compliance wells shall also be screened within residual soils overlying bedrock, to the extent deemed practicable, based on subsurface conditions.

Upon approval from the Director, wells may be removed from the network, added to the network, relocated, constructed, or abandoned as deemed necessary by the facility.

Future wells will be constructed, and existing wells will be abandoned, in accordance with the specifications presented in APPENDIX 4.

4.2 Additional Wells and Piezometers

Nine additional monitoring wells are present at the Greif Packaging industrial landfill: RP-01, MW-02, RP-02, RP-03, MW-04, RP-04, RP-05, RP-06, and RP-07.

The facility is not *required* to measure groundwater levels in additional piezometers during each groundwater sampling event; however, the facility may choose to measure groundwater levels in additional wells and piezometers that are located at the facility.

4.3 Monitoring Well Operation and Maintenance Procedures

During each monitoring event, the monitoring wells will be inspected to ensure that they are performing to design specifications. In the event that a regulatory point-of-compliance well is not functioning to design specifications, the facility will endeavor to either replace or repair the well as necessary, prior to the next regularly scheduled sampling event.

4.4 Evaluation of Monitoring Network

At least annually, the facility shall evaluate the data on static groundwater surface evaluations by preparing a potentiometric surface map to determine whether the groundwater monitoring system continues to meet the requirements for detecting a release. If the evaluation shows that the requirements are no longer satisfied, the facility shall modify the monitoring system prior to the next required monitoring event to meet regulatory requirements.

5.0 SUBSURFACE CONDITIONS

Geologic and hydrogeologic conditions at the landfill are described in this SECTION. A geologic map is presented as FIGURE 6 (APPENDIX 1).

5.1 Geologic Framework

The geology of the Riverville area was mapped and described by Espenshade and Rogers (1940-1942) during their studies of mineral deposits in the James River – Roanoke River iron-manganese mining district. The results of these studies culminated in a geologic map published by Espenshade in 1954 (USGS Bulletin 1008).

Based upon our interpretation of the location of the landfill within the context of the geologic map prepared by Espenshade, the majority of the landfill is believed to be underlain by a greenstone (which Espenshade assigned to the top of the Evington Group).

The northwestern end of the landfill may overlie an area mapped by Espenshade as a relatively narrow band of biotite-muscovite schist member of the Mount Athos Formation.

Further to the northwest (along State Route 622 which generally follows the crest of a NE-SW trending ridge) and just beyond the facility property boundary, Espenshade mapped a quartzite member of the Mount Athos Formation. In the field, the presence of the Mount Athos quartzite is easily confirmed, as it forms conspicuous outcrops along the crest of the ridge and in road cuts along State Route 622. In general, the mineralization studied by Espenshade and Rodgers during the 1940s is associated with the quartzite.

As interpreted by Espenshade, the quartzite is older than the biotite-muscovite schist, which is older than the greenstone. Since the beds generally dip toward the southeast, Espenshade considers the entire sequence to be slightly overturned.

The southeastern end of the landfill appears to be close to a fault where, according to Espenshade, older Archer Creek Formation (marble member) overlies the younger greenstone along a fault. In other words, the older marble has been thrust toward the northwest over the younger greenstone.

Structurally, the area to the southwest of Riverville can be characterized by two striking structural features:

- Based upon the Espenshade map, the subject site appears to be located within a NE-SW trending overturned syncline that plunges toward the southwest.

- Based upon topographic analysis, a series of conspicuous drainages (which discharge into the James River), each trending NW-SE, suggests the presence of a dominant fracture system that is more or less orthogonal to the regional structure fabric (that is, orthogonal to the regional NW-SW trending structural fabric mentioned first). Conversely, the pattern of smaller tributaries to these drainages appears to conform to the regional NW-SW trending structural fabric.

Collectively, we expect these structural features to significantly affect groundwater movement in the vicinity of the landfill.

5.2 Hydrogeologic Conditions

Static water elevation data (APPENDIX 1) indicate that well MW-01 is hydrogeologically upgradient from all disposal areas within the landfill facility, and upgradient from all other wells. In general, groundwater in the uppermost aquifer underlying the facility flows from north to south.

The facility is not aware of any special conditions that may affect the groundwater. In the event that the direction of groundwater flow changes (i.e., changes in relative groundwater elevations between the upgradient well and the downgradient wells), then the monitoring network may be altered (i.e., by constructing additional wells) to adequately monitor the groundwater in the uppermost aquifer.

The rate of contaminant transport may be conservatively estimated by the velocity of groundwater flow. We shall distinguish between the apparent Darcy groundwater flow velocity (V_d) and seepage velocity (V_s), which are given by the equations:

$$V_d = ki$$

and

$$V_s = kin^{-1},$$

where:

V_d = Darcy velocity
V_s = seepage velocity
k = hydraulic conductivity
i = hydraulic gradient
n = porosity

Hydraulic conductivity and intragranular porosity values were obtained from reports prepared by Hatcher-Sayre, Inc. (1989 and 1997). Hydraulic conductivity values range from 2.43 x 10^{-5} m/sec to 4.84 x 10^{-6} m/sec.

In order to remain most protective of human health and the environment, the calculation of velocity is based upon the *maximum* hydraulic conductivity value reported (2.43 x 10^{-5} m/sec).

Based upon the subsurface materials which observation wells were screened, intragranular porosity is estimated to be about 0.45.

Groundwater velocities along a selected flow path (from *upgradient* well *MW-01* and *downgradient* well *MW-06*), as calculated using data derived from multiple sampling events (through November 2020), is approximately *279 feet/year* (TABLE and GRAPHS - APPENDIX 1).

The rate of contaminant transport may be conservatively estimated by the velocity of groundwater flow; however, several processes (dispersion, diffusion, retardation, biodegradation) will serve to reduce the rate and total mass of contaminants transported via groundwater.

6.0 FIRST DETERMINATION MONITORING

Requirements of First Determination monitoring are provided in this section.

6.1 Constituents

The facility shall determine the concentration in groundwater samples of the constituents listed in Table 3.1, Column A.

6.2 Background Sampling Events

Since background sampling events have been completed for First Determination Monitoring, sampling shall be conducted on a semi-annual schedule.

6.3 Semi-Annual Sampling Events

During each semi-annual event, one sample shall be obtained from each well included in the Plan and analyzed for all of the constituents listed in *VSWMR* Table 3.1, Column A.

6.4 Evaluation and Response

After each semi-annual First Determination Monitoring event, the facility shall perform a statistical evaluation of the analytical results comparing each downgradient well to the upgradient well. The facility may choose to apply any of the statistical methods approved by DEQ.

If no Table 3.1, Column A constituents are found to have entered groundwater at statistically significant concentrations over background, the facility shall:

- remain in First Determination Monitoring; and
- may request the director delete any Table 3.1, Column A constituents from the semi-annual sampling list, if the owner or operator demonstrates that the proposed deleted constituents are not reasonably expected to be in, or derived from the waste.

If the owner or operator recognizes a statistically significant increase over background for any Table 3.1, Column A constituent, within ***14 days*** of this finding, the owner or operator shall notify the department identifying the Table 3.1, Column A constituents that have exceeded background levels. The notification shall include a statement that within 90 days the owner or operator shall:

- initiate a Phase II Monitoring Program; or
- submit an Alternate Source Demonstration

6.5 Verification Sampling

The owner or operator may at any time within ***30 days*** of completion of sampling and laboratory analysis (as evidenced by the date posted on the laboratory certificate-of-analysis), obtain verification samples, if the initial review of the analytical data suggests results that might not be an accurate reflection of groundwater quality at the disposal unit boundary.

Verification sampling is a voluntary action and shall not alter the timeframes associated with reporting a statistically significant increase.

6.6 Data Validation

The owner or operator may at any time within ***30 days*** of completion of sampling and laboratory analysis (as evidenced by the date posted on the laboratory certificate-of-analysis), undertake third party data validation of the analytical data received from the laboratory.

Data validation is a voluntary action and shall not alter the timeframes associated with reporting a statistically significant increase.

6.7 Alternate Source Demonstration

As a result of any statistically significant increase and in accordance with *VSWMR*, the owner or operator may submit an ***Alternate Source Demonstration*** report, certified by a qualified groundwater scientist. If a successful demonstration is made, the owner/operator shall continue monitoring in accordance with the First Determination Monitoring Program.

If after ***90 days***, a successful demonstration has not been made, the owner or operator shall initiate an assessment monitoring program in accordance with *VSWMR*. The 90-day Alternate Source Demonstration period may be extended by the Director for good cause.

6.8 Record Keeping and Reporting

The facility shall keep records of the analyses and evaluations throughout the active life of the facility, and throughout the post-closure care period as well.

Such records shall include, but are not limited to, information pertaining to well construction, sampling, laboratory analyses, statistical evaluations, static water levels, Department correspondence to the landfill, and all approved variances, well subsets, wetlands, or other such Director/Department approvals.

In accordance with *VSWMR*, the owner / operator shall:

- submit a report of groundwater sampling and analysis no later than ***120 days*** from the completion of sampling and analysis, for the first semi-annual groundwater sampling event conducted for the calendar year
- submit a report of groundwater sampling and analysis no later than ***120 days*** from the completion of sampling and analysis, for the second semi-annual groundwater sampling event conducted for the calendar year
- submit an ***Annual Groundwater Report*** no later than ***120 days*** from the completion of sampling and analysis, for the second semi-annual groundwater sampling event conducted for the calendar year.

At the discretion of the operator or owner, the second semi-annual groundwater event report may be incorporated into the Annual Groundwater Report.

7.0 PHASE II MONITORING

Requirements of Phase II monitoring are provided in this SECTION.

7.1 Introduction

The facility shall, at a minimum, determine:

- the rate and extent of migration of the solid waste constituents in the groundwater, and
- the concentrations of the solid waste constituents in the groundwater.

7.2 Constituents

A Phase II monitoring program shall include the constituents listed in *VSWMR* Table 3.1, *Column A,* plus any previously detected constituents listed in *VSWMR* Table 3.1, *Column B*.

7.3 Initial Phase II Sampling Event

Within ***90 days*** of noting the exceedance over background under the First Determination Monitoring Program, the facility shall collect groundwater samples from all permitted monitoring wells, for analysis of all constituents listed in *VSWMR* Table 3.1, Column B.

After completing the initial Phase II sampling event, the facility shall continue to sample and analyze groundwater on a semi-annual basis within the Phase II Monitoring Program

7.4 Development of Background

If no additional *VSWMR* Table 3.1, Column B constituents are detected other than those previously detected under Column A, which already have established their background levels, the owner or operator shall establish Groundwater Protection Standards within ***30 days*** of obtaining the results from the initial *VSWMR* Table 3.1, Column B sampling event.

If one or more additional Table 3.1, Column B constituents are detected other than the Column A constituents previously detected during First Determination monitoring, the facility will establish a background value for each additional detected constituent within ***360 days*** of performing the initial Phase II sampling event.

Within ***30 days*** of submitting the Phase II Background Report, the owner or operator shall propose Groundwater Protection Standards for all detected *VSWMR* Table 3.1, Column B constituents.

7.5 Subsequent Phase II Sampling Events

During each semi-annual event, one sample shall be obtained from each well included in the Plan and analyzed for all of the constituents listed in *VSWMR* Table 3.1, Column A plus any previously detected *VSWMR* Table 3.1, Column B constituents.

If the facility finds that any detected Table 3.1, Column B constituent is subsequently not detected for a period of two years, the facility may petition the Director to delete the constituent from the list of detected Table 3.1, Column B constituents that must be sampled semi-annually.

7.6 Groundwater Protection Standards

No later than ***30 days*** after submitting the Phase II Background report, or within ***30 days*** of obtaining the results from the initial Phase II sampling event indicating no further sampling for background determination is necessary, the owner or operator shall propose a Groundwater Protection Standard (GWPS) for each constituent listed in *VSWMR* Table 3.1, Column B that has been detected in the groundwater.

Groundwater Protection Standards shall be selected in accordance with the rules described in SECTION 8. The proposed standards shall be submitted to the Department in letter form, and will be accompanied by all relevant historical concentration data to justify the proposed concentration levels.

7.7 Groundwater Monitoring Plan

No later than ***60 days*** after the approval of Groundwater Protection Standards, the owner or operator shall submit an updated Groundwater Monitoring Plan, which details the site well network and sampling and analysis procedures undertaken during groundwater monitoring events.

The director may waive the requirement for an updated plan if the Groundwater Monitoring Plan included in the facility's permit reflects current site conditions in accordance with the regulations.

No later than ***30 days*** after the submission of the Groundwater Monitoring Plan, the owner or operator shall request a permit amendment to incorporate the updated plan and related groundwater monitoring modules into the facility's permit in accordance with the *VSWMR*.

7.8 Evaluation

After each subsequent monitoring event following the establishment of Groundwater Protection Standards, the concentrations of Table 3.1, Column A constituents (plus any previously-detected Table 3.1, Column B constituents) found in the groundwater at each monitoring well at the waste management unit boundary will be evaluated. The evaluation will be submitted to the Department in a semiannual Phase II Report.

The evaluation shall be based on the following procedures:

- If the concentrations of all *previously-detected* constituents listed in *VSWMR* Table 3.1, Column B (i.e. Table 3.1, Column A + detected Table 3.1, Column B constituents) are shown to be at or below background values, using the statistical procedures in SECTION 13, for two consecutive compliance sampling events, the facility shall notify the Director of this finding and may return to First Determination monitoring.

- If the concentration of any *previously-detected* constituent listed in *VSWMR* Table 3.1, Column B (i.e. Table 3.1, Column A + detected Table 3.1, Column B constituents) is above its facility background value, but all concentrations are less than their respective Groundwater Protection Standard, then the facility shall continue semiannual Phase II monitoring.

- If the concentration of any *previously-detected* constituent listed in *VSWMR* Table 3.1, Column B (i.e. Table 3.1, Column A + detected Table 3.1, Column B constituents) shows a statistically significant increase above its respective Groundwater Protection Standard at any monitoring well at the waste management unit boundary, then the facility shall notify the Department within ***14 days*** of this finding. The notification will include a statement that within ***90 days*** the owner or operator will either undertake the characterization and assessment actions required under *VSWMR*, or submit an ASD.

7.9 Verification Sampling

The owner or operator may at any time within ***30 days*** of completion of sampling and laboratory analysis (as evidenced by the date posted on the laboratory certificate-of-analysis), obtain verification samples, if the initial review of the analytical data suggests results that might not be an accurate reflection of groundwater quality at the disposal unit boundary.

Verification sampling is a voluntary action and shall not alter the timeframes associated with reporting a statistically significant increase.

7.10 Data Validation

The owner or operator may at any time within ***30 days*** of completion of sampling and laboratory analysis (as evidenced by the date posted on the laboratory certificate-of-analysis), undertake third party data validation of the analytical data received from the laboratory.

Data validation is a voluntary action and shall not alter the timeframes associated with reporting a statistically significant increase.

7.11 Alternate Source Demonstration

As a result of any statistically significant increase and in accordance with *VSWMR*, the owner or operator may submit an ***Alternate Source Demonstration*** report, certified by a qualified groundwater scientist. If a successful demonstration is made, the owner/operator shall continue monitoring in accordance with the First Determination Monitoring Program.

If after ***90 days***, a successful demonstration has not been made, the owner or operator shall initiate an assessment monitoring program in accordance with *VSWMR*. The 90-day Alternate Source Demonstration period may be extended by the Director for good cause.

7.12 Nature and Extent

Within ***90 days*** of any *VSWMR* Table 3.1, Column B constituent exceeding its approved Groundwater Protection Standard, and assuming a submitted ASD was not approved, the facility should:

(1) (a) install additional monitoring wells as necessary, sufficient to define the vertical and horizontal extent of the release of constituents….including the installation of at least one additional monitoring well at the facility boundary in the direction of contaminant migration.

(b) notify all persons who own the land or reside on the land that directly overlies any part of the release, if contaminants have migrated off-site as indicated by the sampling of the characterization wells installed under (1)(a) above.

(c) within ***90 days***, initiate an Assessment of Corrective Measures or Proposal for Presumptive Remedy

7.13 Record Keeping and Reporting

The facility shall keep records of the analyses and evaluations throughout the active life of the facility and throughout the post-closure care period as well.

Such records shall include, but are not limited to, information pertaining to well construction, sampling, laboratory analyses, statistical evaluations, static water levels, Department correspondence to the landfill, and all approved variances, well subsets, wetlands, or other such Director/Department approvals.

In accordance with *VSWMR*, the owner / operator shall:

- submit a report of groundwater sampling and analysis no later than ***120 days*** from the completion of sampling and analysis for the first semi-annual groundwater sampling event conducted for the calendar year

- submit a report of groundwater sampling and analysis no later than ***120 days*** from the completion of sampling and analysis for the second semi-annual groundwater sampling event conducted for the calendar year
- submit an ***Annual Groundwater Report*** no later than ***120 days*** from the completion of sampling and analysis for the second semi-annual groundwater sampling event conducted for the calendar year.

At the discretion of the operator or owner, the second semi-annual groundwater event report may be incorporated into the Annual Groundwater Report.

8.0 GROUNDWATER PROTECTION STANDARDS

Groundwater Protection Standards shall be selected from one of the three available alternatives:

- Maximum Contaminant Level (MCL)
- facility background concentration
- health-based Alternate Concentration Limit (ACL)

Groundwater Protection Standards for the subject facility are presented in APPENDIX 3.

8.1 Drinking Water Standards

If EPA *has* promulgated a maximum contaminant level (MCL) for a constituent, and if the facility background concentration is *less than* that MCL, then the GWPS for that constituent shall be the MCL.

Constituents for which EPA has promulgated an MCL, are so indicated on the TABLE in APPENDIX 3.

In the event that EPA changes an existing MCL or promulgates an MCL for an additional constituent, the newly promulgated MCL shall become the Groundwater Protection Standard (except in those cases outlined in SECTIONS 8.2 and 8.3).

8.2 Background Concentration

If EPA has *not* promulgated an MCL for that constituent, and if the Director has *not* promulgated an Alternate Concentration Level (ACL) for that constituent, the GWPS for that constituent shall be the facility background concentration (FBAC).

If EPA *has* promulgated a maximum contaminant level (MCL) for that constituent, or if the Director *has* promulgated an Alternate Concentration Level (ACL) for that constituent, and if the facility background concentration is *greater than* the MCL or ACL, the GWPS for that constituent shall be the facility background concentration (FBAC).

If EPA has *not* promulgated an MCL for a constituent, and if the Director *has* promulgated an Alternate Concentration Level (ACL) for that constituent, and if the ACL is *less than* the laboratory Limit-of-Quantitation (LOQ) for that constituent, the GWPS for that constituent shall be the ACL. The LOQ for that constituent, however, will be used for statistical comparisons.

8.3 Alternate Groundwater Protection Standards

The EPA has *not* established drinking water standards (MCLs) for all constituents listed in *VSWMR* Table 3.1, Column B. Accordingly, DEQ has determined Alternate Concentration Limits (ACLs) for a number of constituents listed in *VSWMR* Table 3.1, Column B that are not associated with MCLs. The ACLs are based on the health effects that may be caused by exposure to these constituents.

If EPA has *not* promulgated an MCL for a constituent, and if the Director has assigned an Alternate Concentration Level (ACL) for that constituent, and if the ACL is *greater than* the laboratory Limit-of-Quantitation (LOQ) for that constituent, then the GWPS for that constituent shall be the ACL.

As of this date, the DEQ has *not* assigned ACLs for *all* constituents listed in *VSWMR* Table 3.1, Column B. Additional ACLs may be developed by the DEQ. Alternatively, ACLs may be calculated by the facility and proposed to the Director.

The Groundwater Protection Standard for each constituent that is not currently associated with an MCL shall be represented by an ACL (except in the special cases outlined in SECTION 8.2).

ACL-based GWPS are updated concurrently with ACL updates. The facility shall use the ACL in effect at the time of sampling, where applicable.

9.0 FIELD PROCEDURES

Groundwater sampling shall be conducted in accordance with the protocols described in this section. Standard methods of purging and sampling are presented below.

9.1 Well Sampling Order

In order to minimize the potential for cross-contamination, upgradient monitoring wells (MW-01, MWB-01, B-12) shall be sampled first.

Downgradient monitoring wells shall be sampled based on constituent levels identified during the previous sampling event, so that the order of downgradient well sampling proceeds from the least impacted well to the most impacted well.

In the event that no significant differences in groundwater impact are observed among wells, field personnel will endeavor to sample the wells around the perimeter of the waste management unit, beginning at upgradient well MW-01 and proceeding either in clockwise or counter-clockwise direction.

9.2 Purging and Sampling Equipment

Permitted monitoring wells will be purged and sampled using dedicated, permanently installed bladder pumps and a micro-purge sampling protocol. The goal of micro-purging is to remove groundwater from the well at a rate that is slow enough to avoid a significant increase in the depth to groundwater during purging (which might disturb the water column).

In the event that a pump fails during a sampling event, or that micro-purging is otherwise deemed impracticable during that event, field personnel will be prepared to purge the affected well using a standard bailer. Bailers may be disposable or non-disposable. Disposable bailers will not be used in more than one well. Non-disposable bailers will be cleaned prior to arriving at the facility, and will not be used in more than one well.

Wells that are sampled to obtain additional quality control shall be sampled in accordance with the same protocol.

At a minimum, field instruments will be used to measure pH, conductivity, and temperature during purging.

When using the micro-purging protocol, field personnel will endeavor to measure pH, conductivity, temperature, dissolved oxygen, oxidation-reduction potential, and turbidity, during purging.

9.3 Purge Volume Calculations for Standard Purge Methods

In the event that a pump fails during a sampling event, or that micro-purging is otherwise deemed impracticable during that event, field personnel will be prepared to purge the affected well using a standard bailer, and the volume of water in the wellpipe shall be calculated by the following procedure:

- At each well, measure the depth to water (DTW) with respect to the top of the PVC wellpipe prior to disturbing the water column. Total depth of the well will be listed on a Purge Data Table.
- Subtract the depth-to-water from the total well depth (TD-DTW) in order to obtain the length of the water column in the wellpipe in feet (L_p).
- In order to obtain the volume of water in the wellpipe (V_p), multiply the length of the water column in feet by a constant that incorporates both the area of the wellpipe and a conversion from cubic feet to gallons per foot.

An example calculation of the constant and final equation for V_p is presented below:

$$V_p = L_{p(ft.)} * K_{p\ (gal/ft.)}$$

where:

$$K_p = \pi * r_{p(ft)}^2 * 1\ ft * 7.48\ gal/ft^3$$

NOTE: when the pipe diameter is 2 inches, K_p= 0.17 gal/ft.

- The minimum volume of water to be purged from the well prior to obtaining samples shall be 3x the volume of water in the wellpipe: $V_{min} = 3V_p$.
- The following exception shall be implemented if a particular well is purged to dryness prior to accumulating 3 wellpipe volumes: The well shall be sampled after allowing the well to recharge with groundwater and within 24 hours of purging.

- The maximum volume of water to be purged from the well prior to obtaining samples shall be 3x the volume of water in the wellpipe plus three times the volume of water in the sandpack: $V_{max} = 3(V_p + V_s)$.

9.4 Sampling Preparation Procedure

Prior to arriving at the site, ice shall be placed in each insulated container along with a small container of water, which will be used measure the temperature inside the insulated container (temperature blank).

Step 1. Prior to sampling the first well, using appropriate standard solutions, ensure that field instruments are properly calibrated.

Step 2. Measure and record the air temperature.

Step 3. Measure and record the temperature of each temperature blank in each insulated container.

9.5 Sampling Procedure

Groundwater samples shall be obtained in accordance with the following steps.

Step 1. Assemble the following items:

- field forms
- sample containers
- container labels
- purge and sample equipment
- electronic water level indicator with measurement accuracy of 0.01 foot
- thermometer having a minimum measurement accuracy of +/-0.1°C
- field meters
- decontamination materials (as specified)
- insulated container containing enough ice (or other cooling agent) to maintain a sample temperature of approximately 4°C (39°F)
- 5-gallon containers (or similar vessel)

- protective clothing (gloves, coat, eyewear, etc.) or any other necessary protective apparatus to shield workers from contaminated groundwater and/or preservatives

Step 2. Record well location and well number.

Put on disposable gloves, unlock and open well. Document condition of well. Measure and record depth to groundwater in the well (static water level) to the nearest 0.01 ft. The reference point, from which the depth to water is measured shall be the top of the PVC wellpipe. Decontaminate the water level indicator, remove, and dispose of the gloves before servicing equipment.

Step 3. Calculate and record the volume of water residing in the well pipe (standard purge volume).

Step 4. Put on disposable gloves. Purge the well. Record time-of-day at which purging is initiated. Measure water quality parameters in order to assess stability of the groundwater derived from the well. Purging shall continue until key water quality parameters have stabilized or until the maximum volume of water has been purged. "Stability" is defined as variation of less than 10% for two consecutive readings.

Collect the purge water in a decontaminated 5-gallon container in order to estimate the volume of water purged from the well.

Low yield wells must be sampled within 24 hours of purging. If yield is insufficient to obtain the required sample volume, document this information and include it in the report of sampling and analysis, which shall be submitted to the Director.

Step 6. Place sample containers on a clean plastic sheet adjacent to the well. Fill the sample containers.

Inspect each sample container prior to use. Do not use containers having an unusual appearance.

Sample jars for analysis of volatile constituents must be filled completely, leaving no head-space between the water sample and the cap. After sealing, inspect the bottle for the presence of any air space. If air bubbles are observed, obtain new samples.

Sample constituents in order of decreasing volatility.

- volatile organic compounds
  - purgeable halocarbons
  - purgeable aromatic hydrocarbons
  - acrolein and acrylonitrile

- semi-volatile organic compounds
  - benzidines
  - phthalate esters
  - nitrosamines
  - PCBs
  - nitroaromatics and cyclic ketones
  - polynuclear aromatic hydrocarbons
  - haloethers
  - chlorinated hydrocarbons
  - pesticides and the herbicides
  - phenols

- total cyanide
- sulfide
- metals

Step 7. Affix to each sample bottle a properly completed sample label listing the following information:

- facility name
- monitoring well identification
- date
- time
- name of collector
- preservation method
- analysis required

Step 8. After obtaining the water samples, immediately place bottles beneath ice in an insulated container. Avoid exposure of samples to direct sunlight.

Step 9. Initiate a Chain-of-Custody form for each sample at the time of collection. This form must accompany each sample from the time of collection to receipt by the laboratory.

Step 10. Secure the monitoring well prior to leaving the well site. Remove and dispose of gloves.

9.6 Sample Preservation and Handling

Samples shall be preserved with the proper preservatives in accordance with *Test Methods for Evaluating Solid Waste - Physical/Chemical Methods, SW-846*.

Prior to sample collection, sample bottles shall be prepared by the selected laboratory. If any or all samples leave the immediate control of the person(s) who obtained, and are responsible for, the samples (eg., during shipment to a laboratory by common carrier), a seal must be placed on the shipping container or on each individual sample. The seal must verify that the samples were not disturbed during transport.

All sample containers shall be packed in an insulated container with ice as soon as they are obtained. Samples shall be transported to the laboratory in this insulated container.

Upon arrival at the laboratory, the temperature of the temperature blank in each insulated container shall be measured and recorded on the Chain-of-Custody form.

In the event that final receipt by the laboratory of any shipping container or sample bottle indicates a broken seal or other evidence of compromised sample integrity, the laboratory shall notify the facility within 24 hours of receipt.

In the event that the integrity of the groundwater sample is compromised, for whatever reason, the well shall be re-sampled for the missing constituent(s) as soon as is feasibly possible. This includes broken containers.

9.7 Decontamination

Between wells, and after the last well, the water level indicator and field instrument probes shall be decontaminated by washing with a phosphate-free, laboratory-grade detergent and rinsing with distilled water or de-ionized water.

9.8 Disposition of Wastewater

All purge and decontamination water that is generated during sampling activities may be discharged to the on-site wastewater treatment plant.

9.9 Information Recorded for Each Sampling Event

The following information shall be recorded, in the field book and/or field data sheets, for each sampling event:

- names of sampling personnel
- order in which wells were sampled
- air temperature
- static water level measurement technique
- well evacuation procedure and equipment
- sample withdrawal procedure and equipment
- types of sample containers used
- preservatives used
- temperature, pH, and conductivity equipment and calibration method
- all pH and specific conductivity calibration measurements with time-of-day
- sample shipping method
- destination
- signature of sampler

Much of this information may also be recorded on the Chain-of-Custody form.

9.10 Information Recorded for Each Well

The following information is unique to each well and shall be recorded, in the field book and/or field data sheets, at the time the well is sampled:

- sampling date
- well identification
- condition of well upon arrival (security, well completion, wellpipe, presence of immiscible layer)
- static water level (measured relative to top PVC wellpipe)
- length of the water column

- volume of water in the wellpipe upon arrival
- volume of water purged (unless micro-purged) OR
  depths to water during purging (when micro-purged)
- pumping rate (unless micro-purged)
- time purging began
- time purging ended
- water quality (stability) parameters (as measured during purging)
- instrument calibration data
- sampling times
- other observations (distinct odors, activities occurring in vicinity of well)

Much of this information may also be recorded on the Chain-of-Custody form.

9.11 Chain-of-Custody

A Chain-of-Custody form meeting minimum informational requirements shall be initiated at each sampling event. This form shall accompany the samples from the time of collection until the samples reach the laboratory.

The information on the Chain-of-Custody form shall be completed by the laboratory upon receiving each sample and by any other person(s) who accepts the sample during transport to some final destination. This document is intended to document an unbroken chain of custody from the field to the laboratory.

The Chain-of-Custody form shall also be used to accurately designate the constituents, for which each sample shall be analyzed.

A sample Chain-of-Custody form is presented APPENDIX 5.

10.0 ANALYTICAL PROCEDURES

The analytical methods set forth in the EPA SW-846 *(Test Methods for Evaluating Solid Waste, latest edition*) shall be used to analyze all constituents.

Acceptable analytical methods are presented on the TABLE in APPENDIX 2.

Metals must be analyzed as *total* metals. Such samples shall not be filtered in the field prior to acidification using nitric acid.

The laboratory shall perform the necessary extraction on all samples, including blanks and duplicates.

11.0 QUALITY ASSURANCE / QUALITY CONTROL

Specifications pertaining to the Quality Assurance and Quality Control programs are described in this section.

11.1 Field Program

Since dedicated equipment is normally to be used at the site, field calibration and a trip blank are considered to meet the minimum requirements for field QA/QC; however, additional blanks may be prepared and analyzed for a more restricted suite of constituents.

Calibration. Field analytical instruments shall be calibrated prior to sampling the first well using standard solutions prepared by the manufacturer of the instrument or other laboratory.

Trip Blank. During each sampling event, a trip blank shall be filled with distilled or de-ionized water in the laboratory that has been selected to conduct the groundwater analyses. The trip blank shall accompany the sampling kit, in the transport container, at all times.

At a minimum, trip blanks will be analyzed for the same volatile organic constituents being analyzed in the groundwater samples.

Field Blank. A field blank will be prepared using distilled or de-ionized laboratory water. At each well site, field personnel will place the field blank in the vicinity of the well and remove the top of the field blank prior to initiating purging. The open-top field blank will remain exposed to ambient conditions while the well is purged and sampled.

At a minimum, field blanks will be analyzed for the same metals being analyzed in the groundwater samples.

Equipment Blank. An equipment or field blank may be analyzed as deemed appropriate (the use of dedicated equipment for purging will not necessitate analysis of equipment blank).

The occurrence of constituents in blank samples may serve to invalidate the analytical results of the affected constituents.

Additional blanks or duplicate samples may be prepared and analyzed to address specific, unanticipated conditions.

11.2 Laboratory Program

The laboratory performing the analytical services shall follow the Quality Assurance / Quality Control (QA/QC) procedures described in the *most current revision* of EPA document SW-846 (*Test Methods for Evaluating Solid Waste*) and any additional requirements presented in this document.

No quantification shall be based solely on library searches. A standard shall be required for all constituents for all methods.

The permissible surrogate recovery range shall not exceed that specified in SW-846 without justification, as judged solely by the facility.

When requested, the laboratory will provide a description of how the internal Limit of Detection (LOD) studies were completed, including identification of the reagent type used in the LOD studies.

Analysis of samples used in matrix-spiking that are diluted beyond quantitation of the spiked compounds may be deemed *unreliable*. The complete spiking, extraction, and analytical process must be repeated with higher matrix-spike levels if dilution of spiked compounds occurs and prevents accurate percent recovery calculations.

Data generated after exceeding the holding time for the specified method may be deemed *unreliable*. If so, then wells affected may be re-sampled for such methods when practicable.

The laboratory accreditation program Virginia Environmental Laboratory Accreditation Program (VELAP), established in the Commonwealth, is required before any environmental analyses performed by a commercial environmental laboratory is used for the purposes of the *Virginia Air Pollution Control Law*, the *Virginia Waste Management Act,* or the *State Water Control Law*. The samples collected during sampling events will only be delivered to laboratories that have received VELAP certification.

12.0 LABORATORY REPORT

Specifications pertaining to the information to be presented on the laboratory report are presented in this section.

12.1 Certificate-of-Analysis

Each Certificate-of-Analysis shall include the following information:

- client name
- client's job number
- site designation
- sample designation
- sample matrix
- constituents analyzed
- date and time obtained
- date and time received by laboratory
- sample preparation method, date, time, analyst
- sample analysis method, date, time, analyst, result
- reporting limit for each constituent
- signature of Laboratory Director or another qualified representative of the laboratory

12.2 Quality Control Report

The operator shall obtain a copy of the internal QA/QC procedures document from the laboratory as warranted.

Should the laboratory choose to subcontract samples for analysis, the analytical results and associated QA/QC documentation from the subcontracted laboratory must be submitted with the primary laboratory's results.

A CLP-equivalent deliverables package will be provided upon request. Such QC reports shall include raw data and chromatograms. The laboratory does not need to be a participant in the Contract Laboratory Program, but must be capable of providing QC information in such a format when requested.

When warranted, the QC report for organic compounds will include information concerning the following:

- Instrument / Tuning Performance Check. Provide statement of adherence to established method performance criteria in all circumstances for the Instrument / Tuning Performance Check. Performance criteria include, but are not limited to analysis of the correct compound, at the required concentration and frequency range and within the relative ion abundance criteria.
- Initial Calibration. Provide statement of adherence to established method requirements. Method requirements vary, but statement should address analysis of the required constituents, at the required number of levels and concentrations, within the required frequency, and within the required response factor and linearity (percent relative standard deviation; %RSD) criteria.
- Verification / Continuing Calibration. Provide statement of adherence to established method requirements. Method requirements vary, but statement should address analysis of the required constituents, at the required level and concentration, within the required frequency, and within the required response factor and precision (percent difference; %D) criteria.
- Method Blanks. Provide statement of adherence to method quality control requirements for method blanks. Statements should address analysis of correct material source, at the required frequency, and within the required criteria for acceptable background levels.
- Sample Matrix Checks. Provide statement of adherence to method requirements. Statements should address accuracy (percent recovery; %R) and precision (relative percent difference; RPD).
- QA/QC Check Samples. Provide statement of adherence to method requirements.
- Provide statement of adherence to method holding times.
- Provide statement of adherence to method criteria regarding GC/MS sensitivity and response stability specifically for standard areas and retention times.
- Provide statement of adherence to surrogate recovery criteria.
- Provide statement of other problems encountered. If no other problems were encountered, then such a condition shall be stated.

When warranted, the QC report for inorganic compounds will include information concerning the following:

- Initial and Continuing Calibration. Provide statement of adherence to calibration compliance requirements.
- Blanks. Include a statement of adherence to method requirements for blanks.
- Laboratory Control Sample (LCS). Provide a statement of adherence to LCS requirements for meeting control limits.
- ICP Interference Check Sample. When ICP methods are required, provide a statement of adherence to method requirements for interference check sample analysis.
- Duplicate Sample Analysis. Provide a statement of adherence to method requirements for duplicate sample analysis.
- Sample Matrix Spike Checks. Provide a statement of adherence to method requirements. Statement should address percent recovery and specified spike recovery control limits.
- Atomic Absorption QC. Provide a statement of adherence to method requirements, which include spike recovery and relative standard deviation (RSD).
- ICP Serial Dilution. When ICP methods are required, provide a statement of adherence to method requirements to include percent difference (%D) of the required dilution to the original result.
- Holding time. Provide a statement of adherence to technical holding times.
- Provide statement of other problems encountered. If no other problems were encountered, then such a condition shall be stated.

When warranted, the QC report will include information concerning the following:

- For those compounds, for which QA/QC performance criteria control limits are not set forth in SW-846, the report shall provide internal control limits.
- Results for diluted samples should be so designated.
- Results determined using the method of standard additions should be so designated.
- Any analyses exceeding the specified holding time (including trip blanks) shall be noted.

- Recoveries for any analyte, which are found to lie beyond the EPA control limits as set forth in SW-846, must be so designated.

The Quality Control report shall be signed by the Laboratory Director or other qualified representative of the laboratory.

13.0 STATISTICAL EVALUATION

Statistical analysis of the groundwater data shall be conducted in accordance with *VSWMR* 9 VAC 20-81-250, or as required under 9 VAC 20-81-260.

Specifically, statistical analysis of the groundwater data presented in monitoring reports for the Greif Packaging LLC Industrial Landfill will be conducted in accordance with current guidance as provided by DEQ (APPENDIX 6) and/or software provided by EPA for these purposes (for example, EPA ProUCL).

The use of EPA ProUCL for statistical analysis is consistent with the criteria defined in *EPA's March 2009 Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities – Unified Guidance (EPA 530 / R-09-007) and the August 2010 Errata Sheet (EPA 530 / R-09-007a).*"

14.0 REFERENCES

Documents consulted in preparing this Plan are referenced in this SECTION.

DAA. 2010. Greif Packaging Industrial Landfill - Groundwater Monitoring Plan (May 2010; revised November 2010).

DAA. 2013. Greif Packaging LLC. Greif Packaging Industrial Landfill. Riverville, Virginia. Groundwater Monitoring Plan DAA Project No. 22299-130 (October 2013).

VDEQ. 2008. *Technical Paper: Data Analysis for Solid Waste Facilities*. Prepared by the Virginia Department of Environmental Quality. Dated March 2008.

VDEQ. Virginia Solid Waste Management Regulations (*VSWMR*). Virginia Waste Management Board.

15.0 LIMITATIONS

This document has been prepared for the exclusive use of the referenced client for specific application to the subject site. This document should in no way be construed as our recommendation to purchase, sell, or develop the project site. This document represents a scientific study and shall not be regarded as certification of the presence of contamination or lack thereof.

The document was prepared in accordance with generally accepted standards of practice for environmental and geological services as conducted by engineering firms of similar size and having similar resources. No other warranty, either expressed or implied, is made.

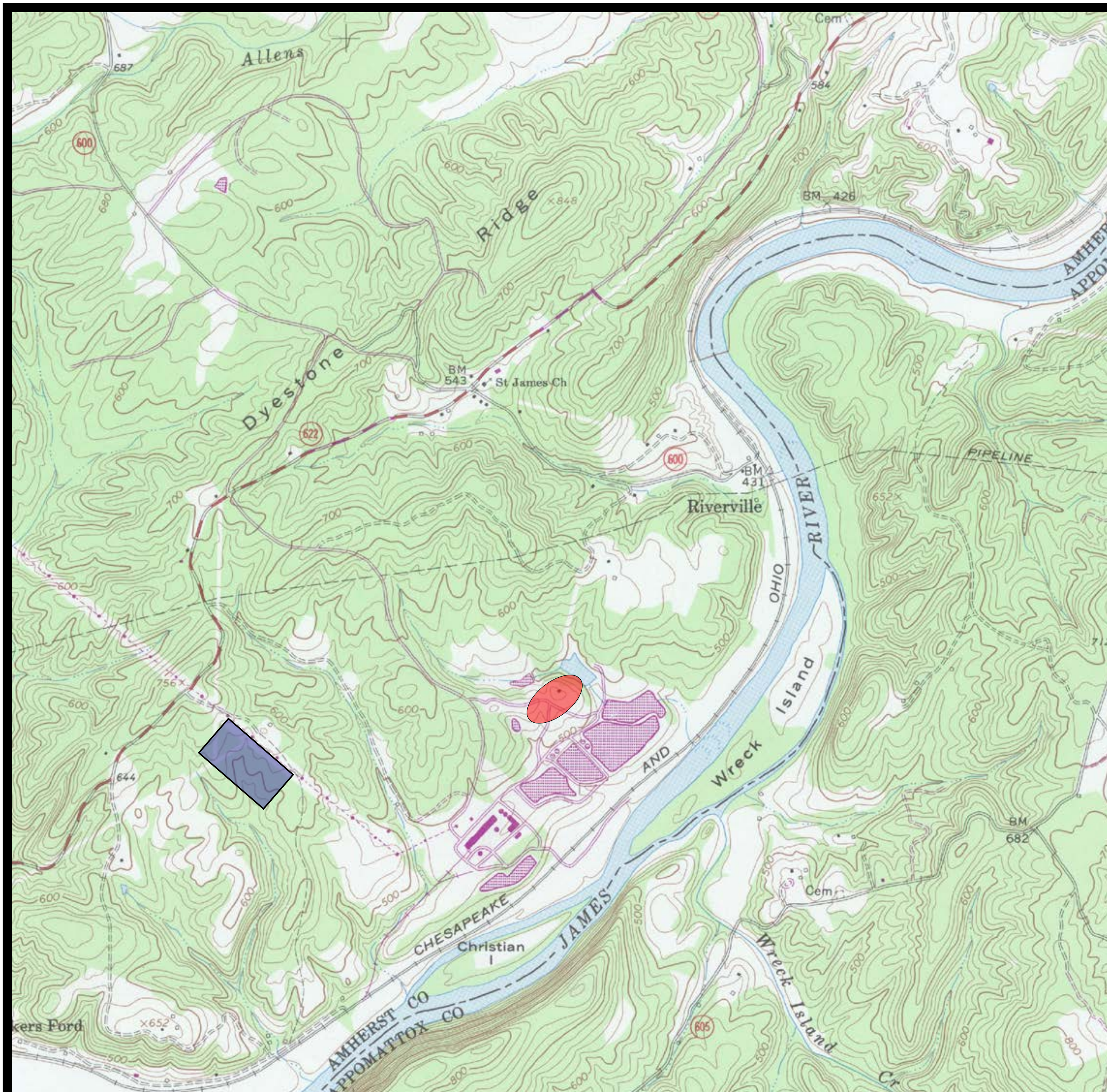
Our conclusions and recommendations are based upon information provided to us by others, our observations, and professional judgment. To the best of our knowledge, information provided by others is true and correct, unless otherwise noted; however, Draper Aden Associates is not responsible for the verification of information provided by others.

Our on-site observations pertain only to specific locations at specific times on specific dates. Our observations and conclusions do not reflect variations in subsurface conditions that may exist between sampling locations, in unexplored areas of the site, or at times other than those represented by our observations.

It is the responsibility of the client to notify the appropriate government agencies of our findings, as may be required by law. Unless contractually specified or required by law, it is not the responsibility of Draper Aden Associates to document these findings to any federal, state and/or local agency.

APPENDIX 1

FIGURES / MAPS / TABLES



LEGEND

industrial landfill (active)

bark landfill (closed)

N

SOURCE: USGS 7.5' quadrangle
Buffalo Ridge, Virginia
1969, Revised 1980

Topographic Map

Client	Greif Packaging LLC
Facility	Riverville Plant [Bark LF / Industrial LF]
Location	Riverville, Virginia
Project	Environmental Monitoring Programs

SCALE: 0 1,000 2,000 Feet

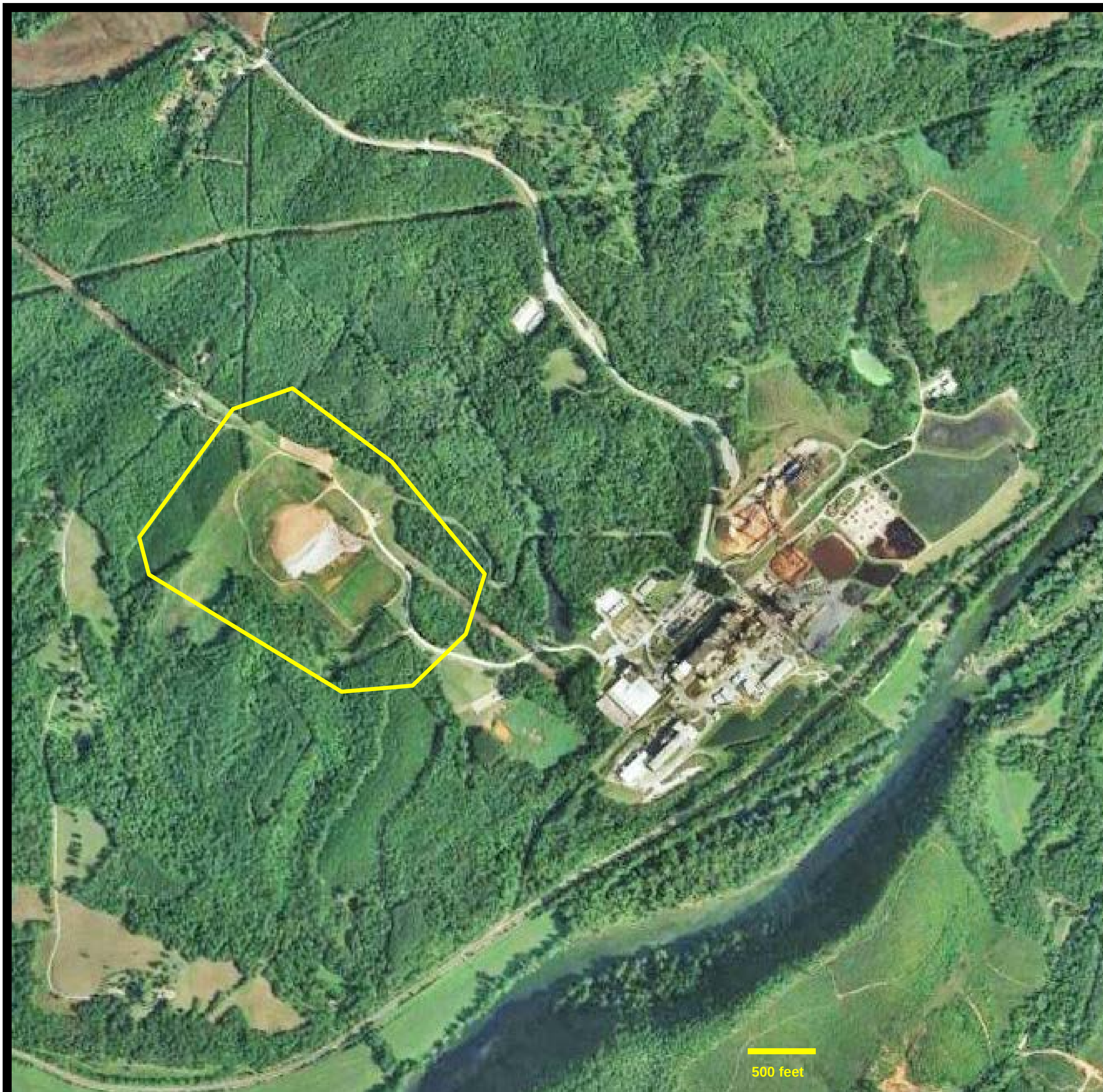
DAA NO. 22299

Draper Aden Associates
Engineering • Surveying • Environmental Services

DESIGNED	LNF
DRAWN	BHH
CHECKED	LNF
DATE	06-22-17

FIGURE

1



LEGEND

approximate location of industrial landfill

N

SOURCE: Commonwealth of Virginia

Aerial Photograph [09-15-15]

Client	Greif Packaging LLC
Facility	Riverville Plant - Industrial Landfill
Location	Riverville, Virginia
Project	Environmental Monitoring Programs

SCALE: as shown

DAA NO. 22299

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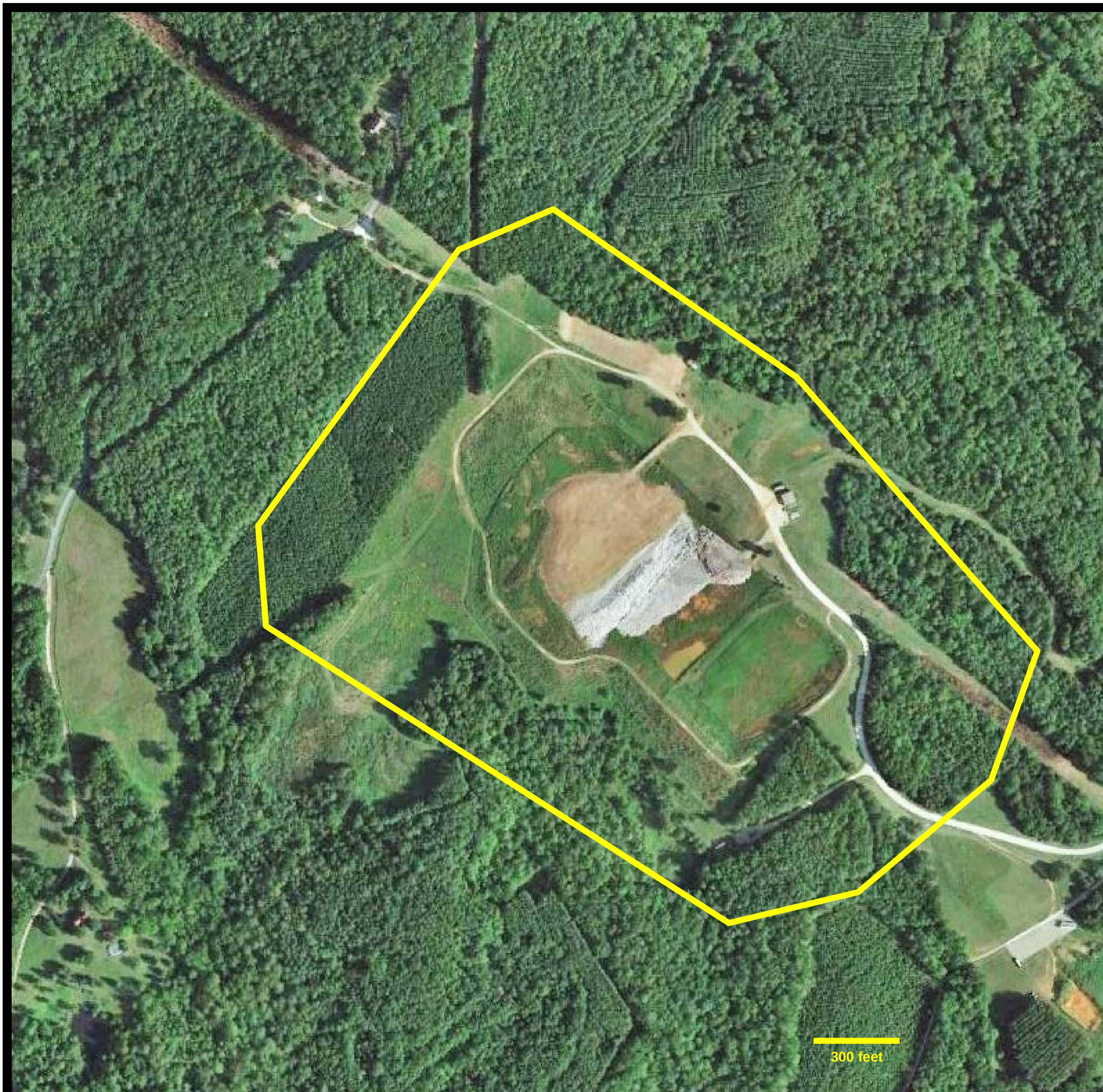
DESIGNED	LNF
DRAWN	BHH
CHECKED	LNF
DATE	04-20-17

FIGURE
2A



LEGEND

approximate location of industrial landfill

N

SOURCE: Commonwealth of Virginia

Aerial Photograph [09-15-15]

Client	Greif Packaging LLC
Facility	Riverville Plant - Industrial LF
Location	Riverville, Virginia
Project	Environmental Monitoring Programs

SCALE: as shown

DAA NO. 22299

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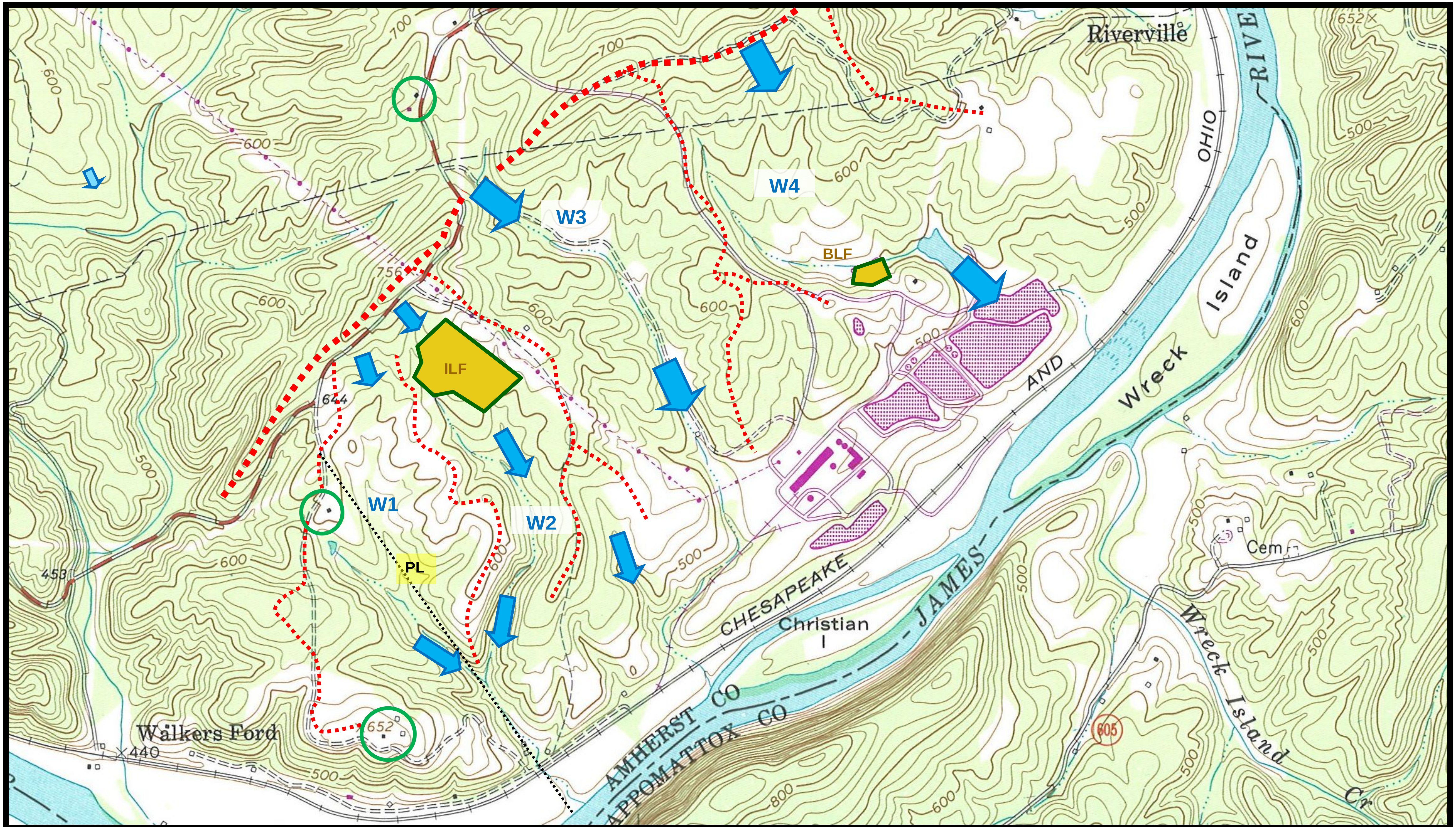
DESIGNED	LNF
DRAWN	BHH
CHECKED	LNF
DATE	04-20-17

FIGURE 2B



Draper Aden Associates

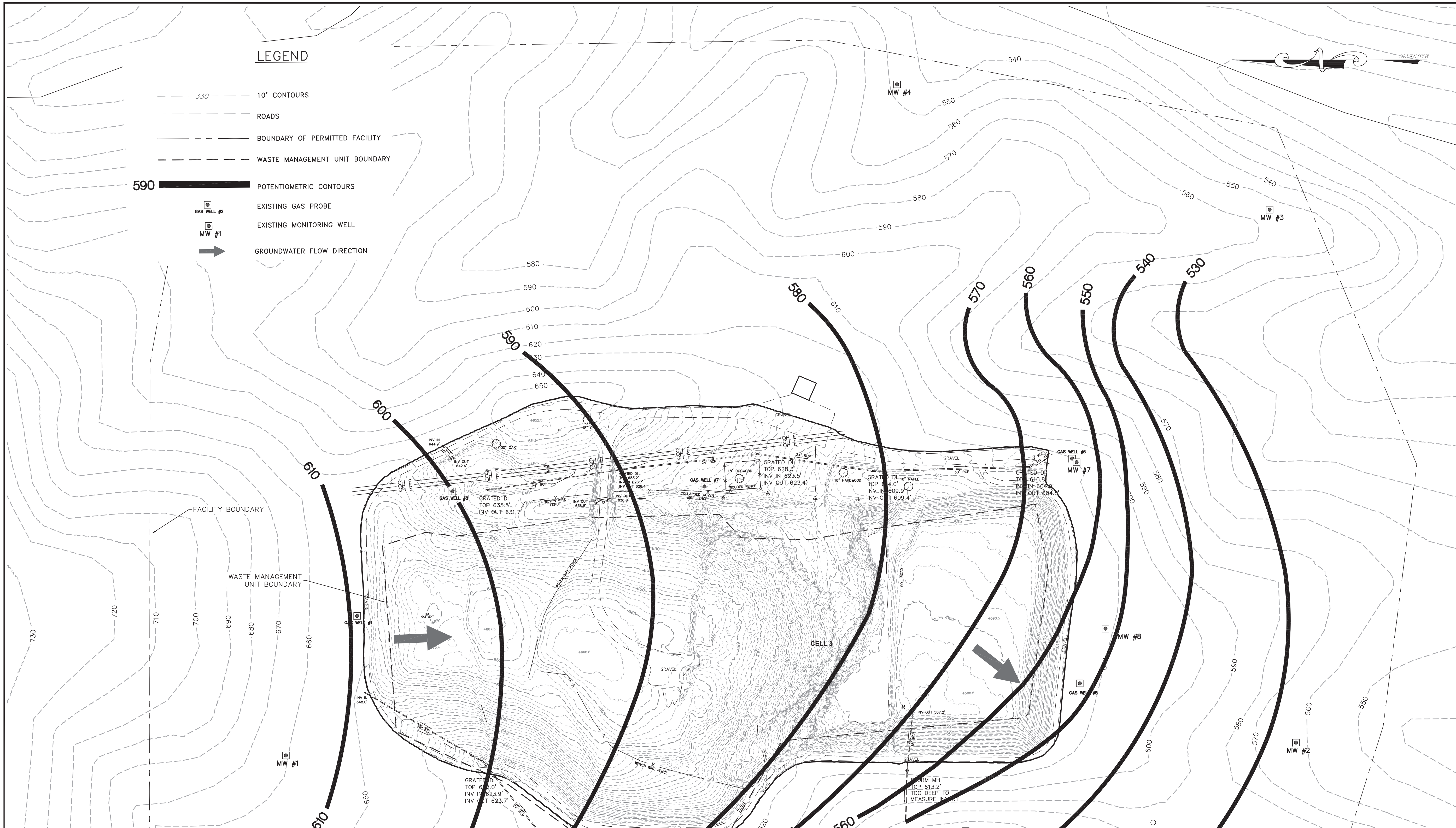
Engineering • Surveying • Environmental Services

Inferred Facility-Wide Groundwater Flow Patterns

Client	Greif Packaging LLC
Facility	Riverville Plant [Bark LF / Industrial LF]
Location	Riverville, Virginia
Project	Environmental Monitoring Programs

DESIGNED	LNF
DRAWN	BHH
CHECKED	LNF
DATE	05-14-12
DAA NO.	22299

FIGURE 3



MONITORING WELL COORDINATE TABLE					
			TOC ELEVATION	WELL DEPTH FROM TOC	ELEVATION GROUND SUFACE
MW#1	N 1090.77	E −480.83	662.37	79.10	660.70
MW#2	N −1106.48	E −453.01	566.23		564.50
MW#3	N −1049.50	E 706.92	554.54		553.30
MW#4	N −239.05	E 979.59	549.33		547.40
MW#5	N −388.03	E −645.65	570.81	38.35	566.49
MW#6	N −659.82	E −696.51	567.00	42.50	564.67
MW#7	N −629.28	E 157.26	612.63	51.50	610.47
MW#8	N −692.35	E −204.88	614.25	79.89	611.25
GAS WELL#1	N 935.68	E −177.22			
GAS WELL#2	N 523.64	E −697.84			
GAS WELL#3	N −43.55	E −789.63			
GAS WELL#4	N −528.75	E −699.87			
GAS WELL#5	N −636.12	E −324.26			
GAS WELL#6	N −623.42	E 161.89			
GAS WELL#7	N 179.80	E 104.57			
GAS WELL#8	N 728.46	E 93.68			

NOTE:

1. TOPOGRAPHIC MAPPING FROM THE 2013 USGS 7.5−MINUTE SERIES OF BUFFALO RIDGE, VA.
2. LANDFILLED TOPOGRAPHY UPDATED BY DRAPER ADEN ASSOCIATES 11−20−18. THIS TOPOGRAPHIC SURVEY, WITH COMPILED BOUNDARY WAS COMPLETED UNDER THE DIRECT AND RESPONSIBLE CHARGE OF ROBERT J. BONK, L.S. FROM AN ACTUAL AERIAL SURVEY; THE IMAGERY AND/OR ORIGINAL DATA WAS OBTAINED ON NOVEMBER 20, 2018 AND THIS PLAT AND/OR MAP MEETS MINIMUM ACCURACY STANDARDS UNLESS OTHERWISE NOTED.
3. THIS SURVEY WAS PREPARED WITHOUT THE BENEFIT OF A TITLE COMMITMENT OR TITLE REPORT AND ALL EASEMENTS AND ENCUMBRANCES THAT MIGHT BE DISCLOSED IN A TITLE SEARCH MAY NOT BE SHOWN.
4. THIS TOPOGRAPHIC SURVEY DOES NOT REPRESENT A CURRENT BOUNDARY SURVEY BY DRAPER ADEN ASSOCIATES AND DRAPER ADEN ASSOCIATES ASSUMES NO LIABILITY FOR REUSE OR MODIFICATION OF THIS DOCUMENT.

MONITORING WELL	DATE	STATIC WATER ELEVATION
MW−1	11/25/19	618.07
MW−2	11/25/19	529.49
MW−5	11/25/19	544.09
MW−6	11/25/19	533.81
MW−7	11/25/19	565.92
MW−8	11/25/19	552.15

GRAPHIC SCALE

(IN FEET)
1 inch = 100ft.

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Hampton Roads, VA
Coats, NC

POTENTIOMETRIC SURFACE MAP: 2019

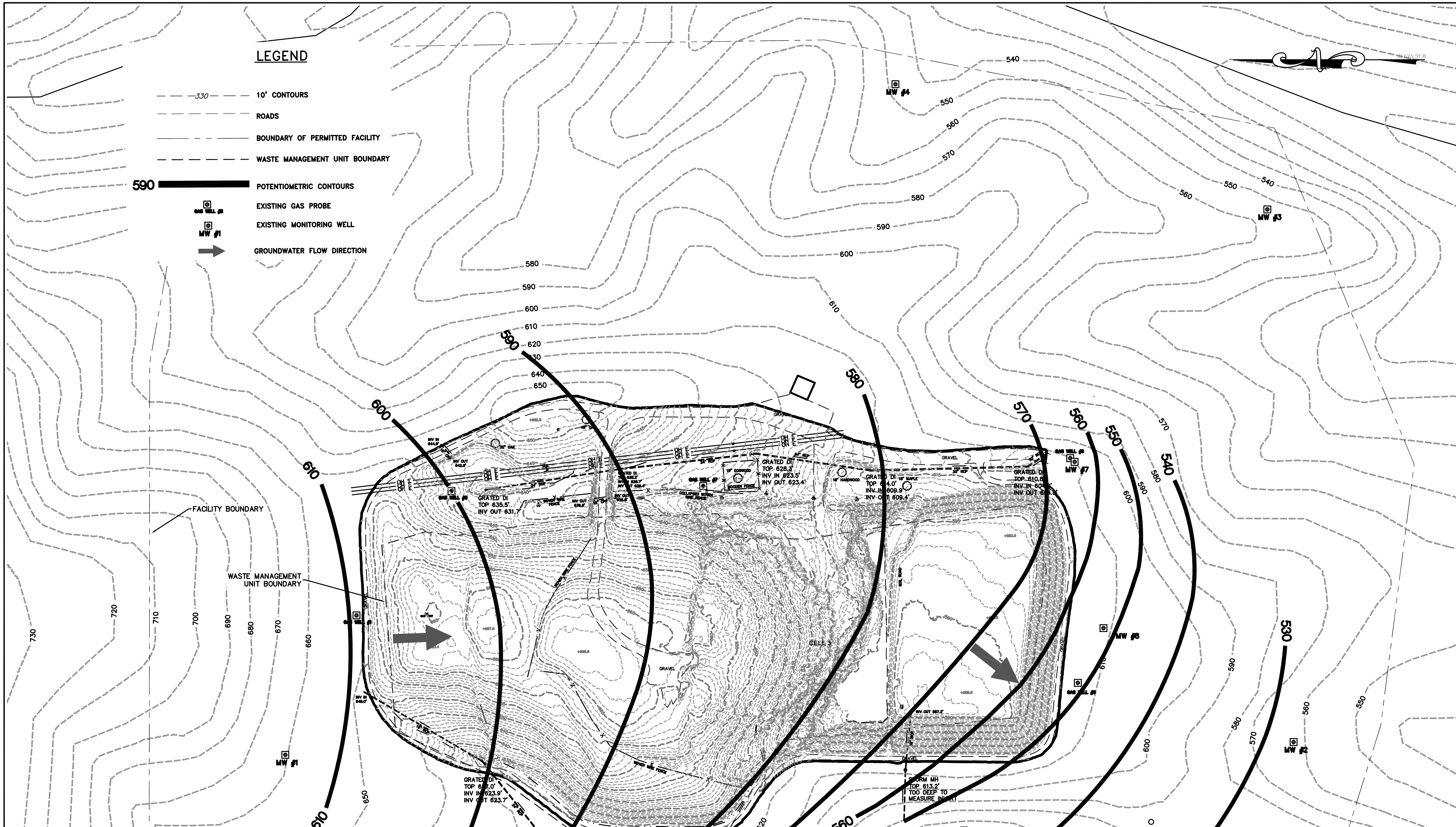
GREIF PACKAGING, LLC

AMHERST, VIRGINIA

REVISIONS

DESIGNED BY: JCN
DRAWN BY: JCN
CHECKED BY: JCN
SCALE: 1" = 100'
DATE: 03/05/20
PROJECT NUMBER: 22299-173-05

FIG. 1



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MW#5	N −388.03	E −645.65	570.81	38.35	566.49
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MONITORING WELL	DATE	STATIC WATER ELEVATION
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MW−2	11/30/20	529.81
MW−5	11/30/20	547.25
MW−6	11/30/20	536.45
MW−7	11/30/20	569.83
MW−8	11/30/20	553.22

GRAPHIC SCALE
(IN FEET)
1 inch = 100 ft.

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Charlottesville, VA
Hampton Roads, VA
Coats, NC

POTENTIOMETRIC SURFACE MAP: 2020 S2

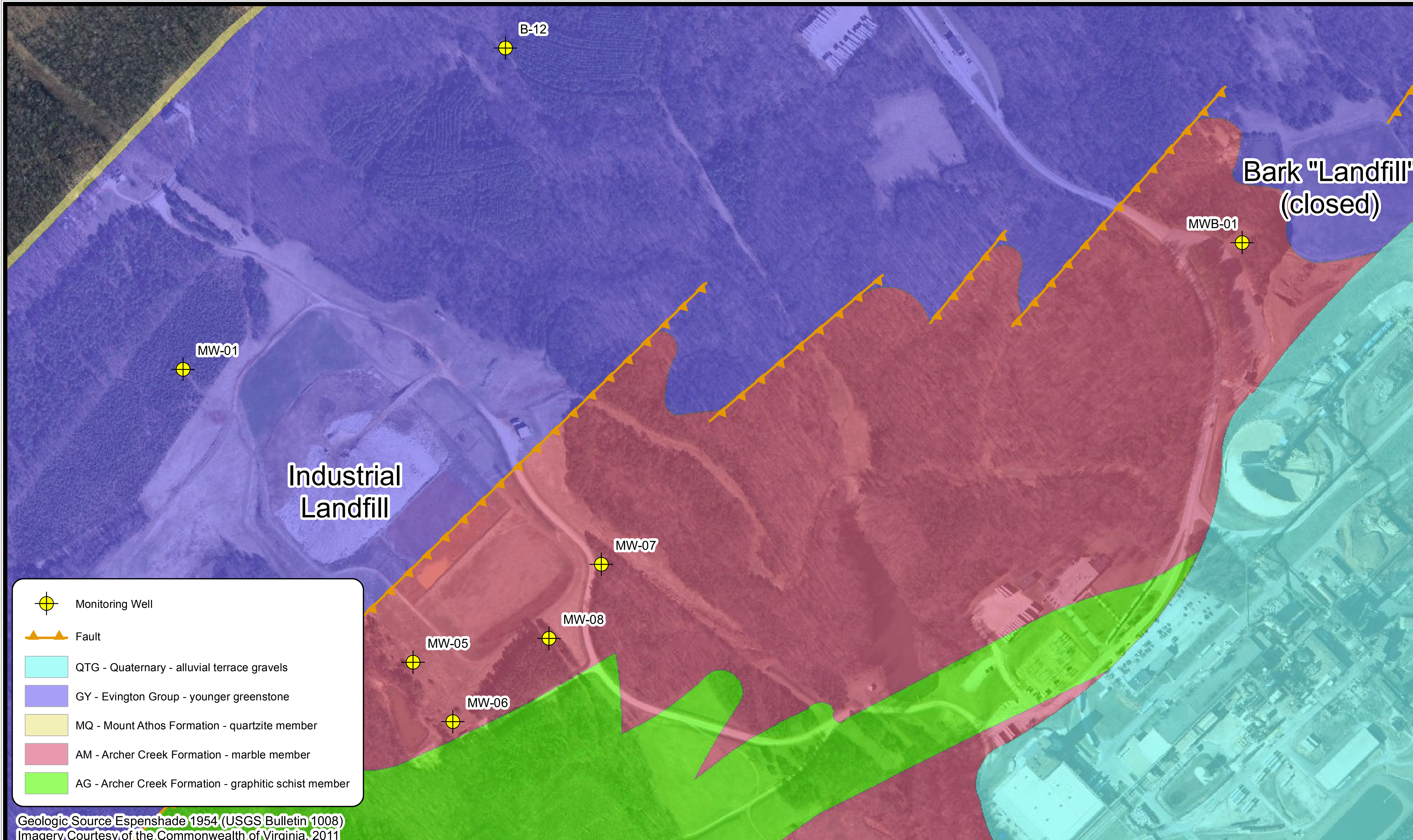
GREIF PACKAGING, LLC

AMHERST, VIRGINIA

REVISIONS

DESIGNED BY: JCN
DRAWN BY: JCN
CHECKED BY: LNF
SCALE: 1" = 100'
DATE: 02/18/21
PROJECT NUMBER: 22299-173-09

FIG. 1



Draper Aden Associates
Engineering • Surveying • Environmental Services
Blacksburg, VA Charlottesville, VA Hampton Roads, VA Richmond, VA

GREIF RIVERVILLE GEOLOGY MAP

Amherst County, Virginia

DAA# 22299-101

CLIENT: GREIF PACKAGING LLC
FACILITY: INDUSTRIAL WASTE LANDFILL
LOCATION: RIVERVILLE, AMHERST COUNTY, VIRGINIA
PROJECT: GROUNDWATER MONITORING PROGRAM

HISTORY OF STATIC WATER ELEVATIONS - MONITORING WELLS

DATE	MW-01	MWB-01	B-12	MW-02	MW-03	MW-04	MW-05	MW-06	MW-07	MW-08
07-02-97	626.06						544.00	535.40	566.70	
08-97	625.32			531.66	518.64	542.38	543.69	535.10	566.13	
01-07-98	622.83						543.61	534.59	564.26	
01-13-99	623.63			530.58	517.86	542.45	543.14	538.32	561.07	
07-19-99	623.29			529.20	517.47	541.19	543.46	534.16	562.79	
01-12-00	621.61			527.97	514.59	542.87	543.57	532.90	563.99	
07-31-00	621.10			527.84	513.76	541.92	543.52	533.63	563.58	
01-16-01	619.45						542.94	533.63	562.75	
07-26-01	618.87				509.94	541.40	543.42	533.85	563.22	
01-15-02	617.28						542.35	532.75	561.64	
04-09-02	616.85				509.48	542.28	541.90	532.69	560.24	
07-09-02	616.14			525.22		540.29	542.66	532.35	561.24	
10-02-02	615.28			523.83		539.34	542.21	531.77	560.72	
03-26-03	615.68						545.10	533.75	564.33	
09-17-03	621.18			525.00		540.36	545.42	535.75	569.01	
03-29-04	622.78						545.86	535.88	567.65	
09-14-04	623.23			526.67		540.92	544.50	534.95	565.68	
03-15-05	622.68						545.22	534.95	566.23	
09-14-05	624.10			526.17		540.66	544.22	534.25	565.47	
03-14-06	625.28						545.22	534.51	565.33	
09-27-06	624.62			526.36		542.44	543.82	534.05	563.88	
03-20-07	627.32			527.32			544.87	535.01	565.86	
09-18-07	628.02						543.93	532.80	565.24	
03-13-08	624.63			527.57		542.88	543.29	531.59	563.08	
09-17-08	624.73						542.95	530.24	562.68	
03-19-09	623.32			526.33		542.43	543.06	530.41	562.64	
09-30-09	624.36			527.02		543.31	543.27	530.77	563.51	
03-10-10	627.18						546.26	535.13	568.52	
09-08-10	627.13	525.84	564.61	531.09		543.34	544.55	533.09	566.84	
03-16-11	624.03	525.11	566.05	529.70			544.55	533.44	564.74	
09-15-11	621.92	523.44	564.27				543.49	531.38	563.58	
03-29-12	623.39	525.75	566.11	527.67			544.66	532.09	564.48	548.20
09-27-12	619.13	522.95	564.01	526.68			543.22	528.63	563.28	548.16
04-04-13	617.36	523.96	565.69	525.71			543.26	530.99	562.39	546.60
10-23-13	616.92	524.88	564.97	527.55			544.10	531.61	564.77	548.66
05-14-14	618.15	527.68	566.32	529.09			545.92	534.85	566.58	551.64
11-19-14	617.83	523.82	564.56	529.24			543.67	532.62	565.27	551.25
05-27-15	616.52	525.88	565.41	528.42			544.76	533.04	565.75	550.16
12-07-15	615.47	524.53	565.67	528.29			544.00	532.80	564.23	548.76
06-14-16	617.67	524.66	566.75	527.23			544.31	534.05	565.78	549.25
12-14-16	617.71	525.27	565.83	527.11			544.13	533.39	566.28	549.88
06-14-17	615.96	525.82	565.57	528.00			544.46	533.25	565.51	549.96
12-12-17	614.66	523.07	564.58	527.57			543.48	531.81	563.53	548.60
06-27-18	613.92	524.97	565.12	528.79			544.66	532.99	564.47	548.24
12-18-18	614.12	526.51	566.38	526.43			546.43	529.77	567.43	550.34
06-19-19	618.70	528.72	566.29	531.67			546.29	535.89	570.49	555.35
11-25-19	618.07	524.57	565.14	529.49			544.09	533.81	565.92	552.15
06-04-20	618.07	527.46	566.16				546.04	535.78	568.11	552.35
11-30-20	618.24	527.79	566.33	529.81			547.25	536.45	569.83	553.22
MIN	613.92	522.95	564.01	523.83	509.48	539.34	541.90	528.63	560.24	546.60
MAX	628.02	528.72	566.75	531.67	518.64	543.34	547.25	538.32	570.49	555.35
MEAN	620.65	525.37	565.52	527.89	514.53	541.79	544.18	533.41	564.83	550.15
RANGE	14.10	5.77	2.74	7.84	9.16	4.00	5.35	9.69	10.25	8.75
STD	3.97	1.55	0.77	1.83	3.46	1.13	1.16	1.87	2.27	2.11

22299-173-09

CLIENT: GREIF PACKAGING LLC
FACILITY: INDUSTRIAL LANDFILL
LOCATION: AMHERST COUNTY, VIRGINIA
PROJECT: GROUNDWATER MONITORING PROGRAM

GROUNDWATER VELOCITY CALCULATIONS

date	from ... upgradient location	upgradient SWE	... toward downgradient location	downgradient SWE	distance	meters/meter gradient	meters/yr GW velocity	feet/yr GW velocity
3/26/2003	MW-01	615.68	MW-06	533.75	1730	4.74E-02	80.6	264.6
9/17/2003	MW-01	621.18	MW-06	535.75	1730	4.94E-02	84.1	275.9
3/29/2004	MW-01	621.18	MW-06	535.75	1730	4.94E-02	84.1	275.9
9/14/2004	MW-01	623.23	MW-06	534.95	1730	5.10E-02	86.9	285.1
3/15/2005	MW-01	622.68	MW-06	534.95	1730	5.07E-02	86.4	283.3
9/14/2005	MW-01	624.10	MW-06	534.25	1730	5.19E-02	88.4	290.2
3/14/2006	MW-01	625.28	MW-06	534.51	1730	5.25E-02	89.4	293.1
9/27/2006	MW-01	624.62	MW-06	534.05	1730	5.24E-02	89.2	292.5
3/20/2007	MW-01	627.32	MW-06	535.01	1730	5.34E-02	90.9	298.1
3/20/2007	MW-01	627.32	MW-06	535.01	1730	5.34E-02	90.9	298.1
9/18/2007	MW-01	628.02	MW-06	532.80	1730	5.50E-02	93.7	307.5
3/13/2008	MW-01	624.63	MW-06	531.59	1730	5.38E-02	91.6	300.5
9/17/2008	MW-01	624.73	MW-06	530.24	1730	5.46E-02	93.0	305.2
3/19/2009	MW-01	623.32	MW-06	530.41	1730	5.37E-02	91.5	300.1
9/30/2009	MW-01	624.36	MW-06	530.77	1730	5.41E-02	92.1	302.3
3/10/2010	MW-01	627.18	MW-06	535.13	1730	5.32E-02	90.6	297.3
9/8/2010	MW-01	627.13	MW-06	533.09	1730	5.44E-02	92.6	303.7
3/16/2011	MW-01	624.03	MW-06	533.44	1730	5.24E-02	89.2	292.6
9/15/2011	MW-01	621.92	MW-06	531.38	1730	5.23E-02	89.1	292.4
3/29/2012	MW-01	623.39	MW-06	532.09	1730	5.28E-02	89.9	294.9
9/27/2012	MW-01	619.13	MW-06	528.63	1730	5.23E-02	89.1	292.3
4/4/2013	MW-01	617.36	MW-06	530.99	1730	4.99E-02	85.0	278.9
10/23/2013	MW-01	616.92	MW-06	531.61	1730	4.93E-02	84.0	275.5
5/14/2014	MW-01	618.15	MW-06	534.85	1730	4.82E-02	82.0	269.0
11/19/2014	MW-01	617.83	MW-06	532.62	1730	4.93E-02	83.9	275.2
5/27/2015	MW-01	616.52	MW-06	533.04	1730	4.83E-02	82.2	269.6
12/7/2015	MW-01	615.47	MW-06	532.8	1730	4.78E-02	81.4	267.0
6/14/2016	MW-01	617.67	MW-06	534.05	1730	4.83E-02	82.3	270.1
12/14/2016	MW-01	617.71	MW-06	533.39	1730	4.87E-02	83.0	272.3
6/14/2017	MW-01	615.96	MW-06	533.25	1730	4.78E-02	81.4	267.1
12/12/2017	MW-01	614.66	MW-06	531.81	1730	4.79E-02	81.6	267.6
6/27/2018	MW-01	613.92	MW-06	532.99	1730	4.68E-02	79.7	261.4
12/18/2018	MW-01	614.12	MW-06	529.77	1730	4.88E-02	83.0	272.4
6/19/2019	MW-01	618.70	MW-06	535.89	1730	4.79E-02	81.5	267.4
11/25/2019	MW-01	618.07	MW-06	533.81	1730	4.87E-02	82.9	272.1
6/4/2020	MW-01	618.07	MW-06	535.78	1730	4.76E-02	81.0	265.8
11/30/2020	MW-01	618.24	MW-06	536.45	1730	4.73E-02	80.5	264.1

median = 85.0 | 278.9

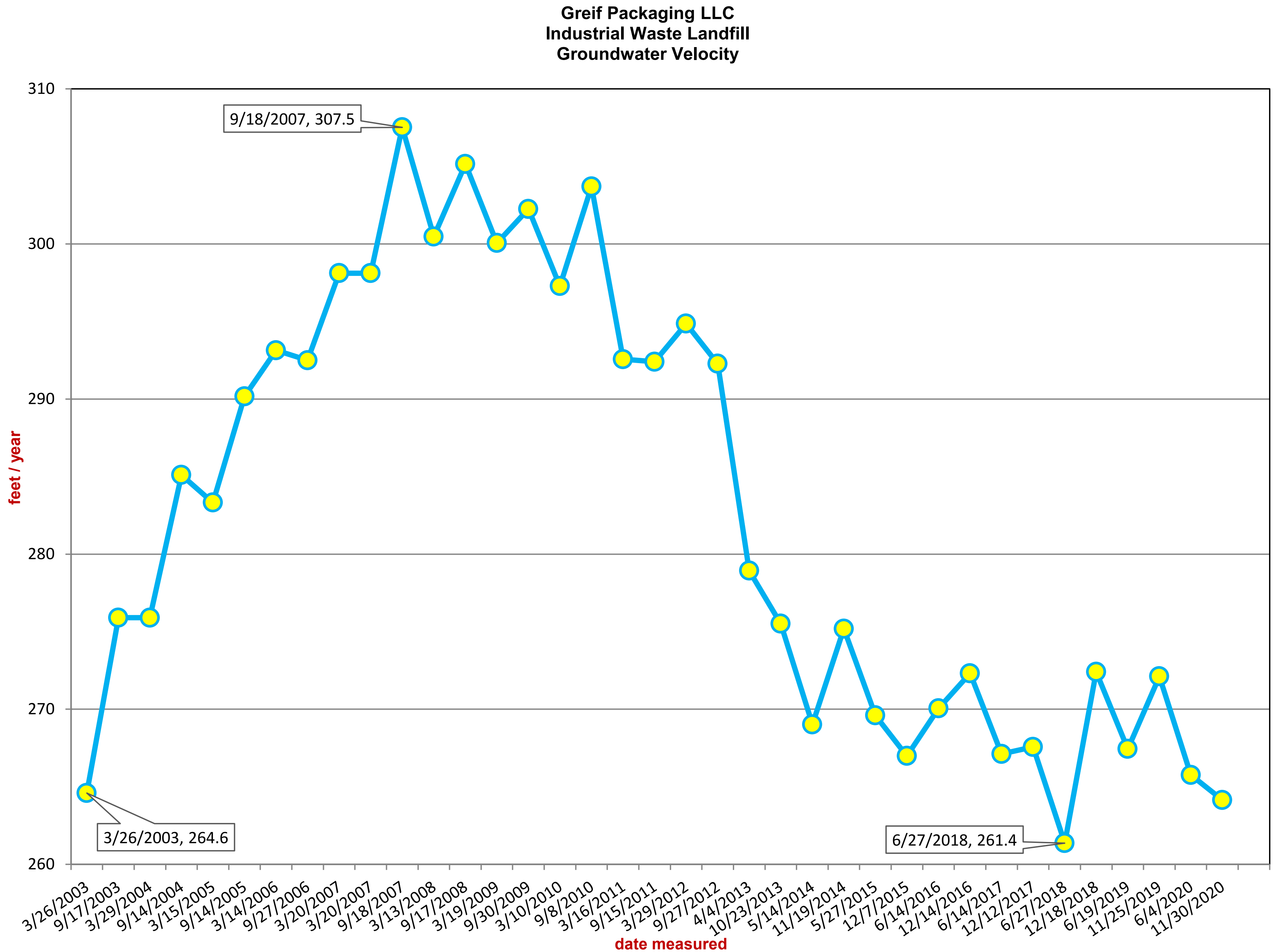
deviation (most recent event) = -5.3%

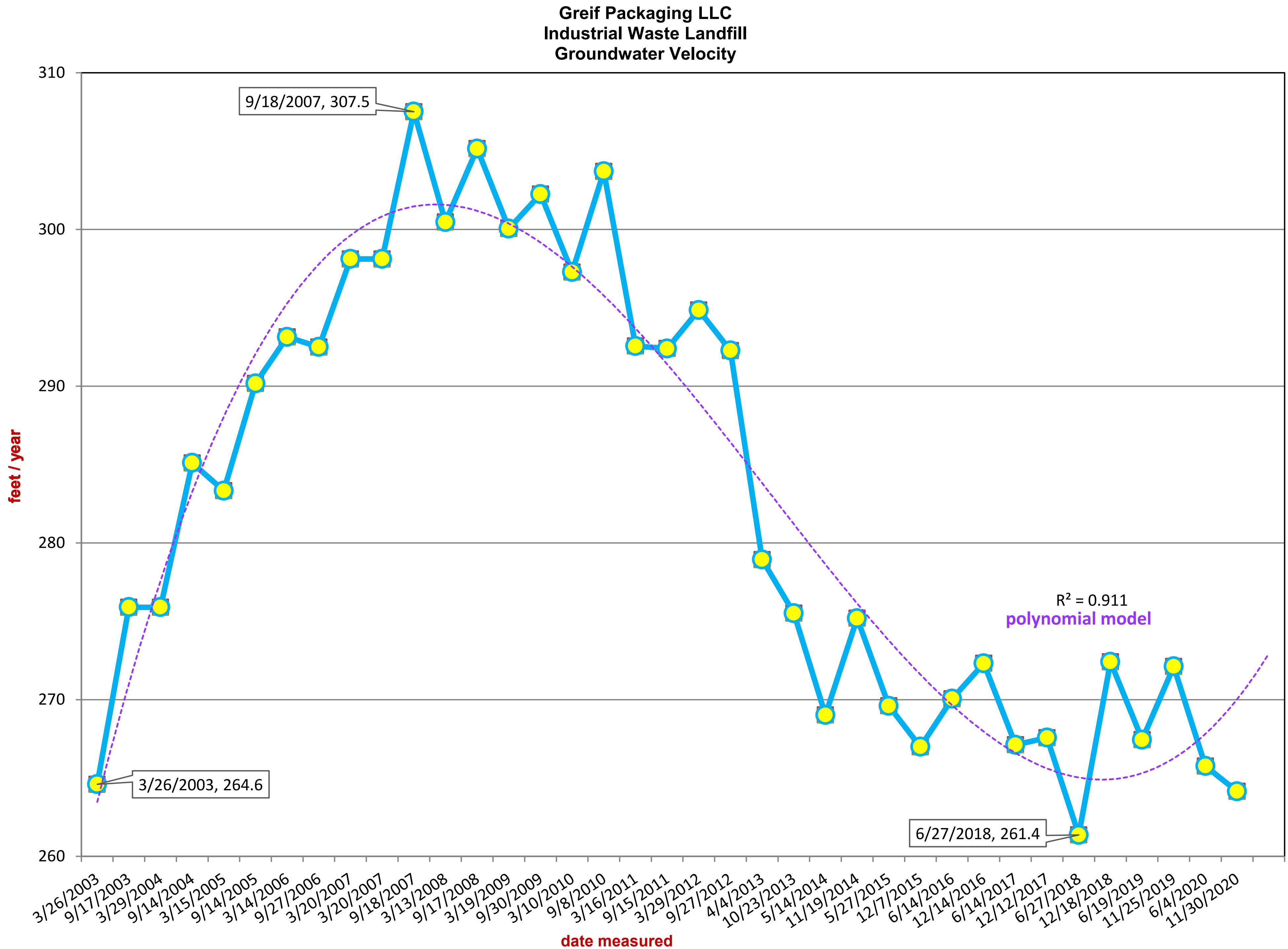
distance = 1,730 feet

hydraulic conductivity = 2.43E-5 meters / second

estimated porosity = 0.45

22299-173-09


Greif Packaging LLC
Industrial Waste Landfill
Groundwater Velocity
310
300
290
280
270
260
feet / year
9/18/2007, 307.5
3/26/2003, 264.6
6/27/2018, 261.4
3/26/2003
9/17/2003
3/29/2004
9/14/2004
3/15/2005
9/14/2005
3/14/2006
9/27/2006
3/20/2007
3/20/2007
9/18/2007
3/13/2008
9/17/2008
3/19/2009
9/30/2009
3/10/2010
9/8/2010
3/16/2011
9/15/2011
3/29/2012
9/27/2012
4/4/2013
10/23/2013
5/14/2014
11/19/2014
5/27/2015
12/7/2015
6/14/2016
12/14/2016
6/14/2017
12/12/2017
6/27/2018
12/18/2018
6/19/2019
11/25/2019
6/4/2020
11/30/2020
date measured



Greif Packaging LLC
Industrial Waste Landfill
Groundwater Velocity
feet / year
date measured
310
300
290
280
270
260
9/18/2007, 307.5
3/26/2003, 264.6
6/27/2018, 261.4
R² = 0.911
polynomial model
3/26/2003
9/17/2003
3/29/2004
9/14/2004
3/15/2005
9/14/2005
3/14/2006
9/27/2006
3/20/2007
3/20/2007
9/18/2007
3/13/2008
9/17/2008
3/19/2009
9/30/2009
3/10/2010
9/8/2010
3/16/2011
9/15/2011
3/29/2012
9/27/2012
4/4/2013
10/23/2013
5/14/2014
11/19/2014
5/27/2015
12/7/2015
6/14/2016
12/14/2016
6/14/2017
12/12/2017
6/27/2018
12/18/2018
6/19/2019
11/25/2019
6/4/2020
11/30/2020

APPENDIX 2

ACCEPTABLE ANALYTICAL METHODS

CLIENT: GREIF PACKAGING LLC.
FACILITY: INDUSTRIAL LANDFILL
LOCATION: RIVERVILLE, VIRGINIA
PROJECT: GROUNDWATER MONITORING PROGRAM

ACCEPTABLE ANALYTICAL METHODS
VSWMR TABLE 3.1 (column A + column B)

PARAMETER[1]	CLASS[2]	CAS RN[3]	METHOD[4]
Acenaphthene	semi-volatile	83-32-9	8270E
Acenaphthylene	semi-volatile	208-96-8	8270E
Acetone	volatile	67-64-1	8260D
Acetonitrile (methyl cyanide)	volatile	75-05-8	8260D
Acetophenone	semi-volatile	98-86-2	8270E
2-Acetylaminofluorene	semi-volatile	53-96-3	8270E
Acrolein	volatile	107-02-8	8260D
Acrylonitrile	volatile	107-13-1	8260D
Aldrin	pesticide	309-00-2	8081A
Allyl chloride	volatile	107-05-1	8260D
4-Aminobiphenyl	semi-volatile	92-67-1	8270E
Anthracene	PNA	120-12-7	8270E
Antimony	metal	Total	6020B
Arsenic	metal	Total	6010D
Barium	metal	Total	6010D
Benzene	volatile	71-43-2	8260D
Benzo[a]anthracene	PNA	56-55-3	8270E
Benzo[b]fluoranthene	PNA	205-99-2	8270E
Benzo[k]fluoranthene	PNA	207-08-9	8270E
Benzo[ghi]perylene	PNA	191-24-2	8270E
Benzo[a]pyrene	PNA	50-32-8	8310
Benzyl alcohol	semi-volatile	100-51-6	8270E
Beryllium	metal	Total	6010D
alpha-BHC	pesticide	319-84-6	8081A
beta-BHC	pesticide	319-85-7	8081A
delta-BHC	pesticide	319-86-8	8081A
gamma-BHC(Lindane)	pesticide	58-89-9	8081A
Bis (2-chloroethoxy) methane	semi-volatile	111-91-1	8270E
Bis (2-chloroethyl) ether	semi-volatile	111-44-4	8270E
Bis (2-chloro-1-methylethyl) ether	semi-volatile	108-60-1	8270E
Bis (2-ethylhexyl) phthalate / di(2-ethylhexyl)phthalate	semi-volatile	117-81-7	8270E
Bromochloromethane	volatile	74-97-5	8260D

CLIENT: GREIF PACKAGING LLC.
FACILITY: INDUSTRIAL LANDFILL
LOCATION: RIVERVILLE, VIRGINIA
PROJECT: GROUNDWATER MONITORING PROGRAM

ACCEPTABLE ANALYTICAL METHODS
VSWMR TABLE 3.1 (column A + column B)

PARAMETER[1]	CLASS[2]	CAS RN[3]	METHOD[4]
Bromodichloromethane	volatile	75-27-4	8260D
Bromoform	volatile	75-25-2	8260D
4-Bromophenyl phenyl ether	semi-volatile	101-55-3	8270E
Butyl benzyl phthalate	semi-volatile	85-68-7	8270E
Cadmium	metal	Total	6010D
Carbon disulfide	volatile	75-15-0	8260D
Carbon tetrachloride	volatile	56-23-5	8260D
Chlordane	pesticide	See Notes	8081A
p-Chloroaniline	semi-volatile	106-47-8	8270E
Chlorobenzene / monochlorobenzene	volatile	108-90-7	8260D
Chlorobenzilate	semi-volatile	510-15-6	8270E
p-Chloro-m-cresol	semi-volatile	59-50-7	8270E
Chloroethane	volatile	75-00-3	8260D
Chloroform	volatile	67-66-3	8260D
2-Chloronaphthalene	semi-volatile	91-58-7	8270E
2-Chlorophenol	semi-volatile	95-57-8	8270E
4-Chlorophenyl phenyl ether	semi-volatile	7005-72-3	8270E
Chloroprene	volatile	126-99-8	8260D
Chromium	metal	Total	6010D
Chrysene	PNA	218-01-9	8270E
Cobalt	metal	Total	6020B
Copper	metal	Total	6010D
m-Cresol	semi-volatile	108-39-4	8270E
o-Cresol	semi-volatile	95-48-7	8270E
p-Cresol	semi-volatile	106-44-5	8270E
Cyanide		57-12-5	9010
2,4-Dichlorophenoxyacetic acid (2,4-D)	herbicide	94-75-7	8151A
4,4'-DDD	pesticide	72-54-8	8081A
4,4'-DDE	pesticide	72-55-9	8081A
4-4'-DDT	pesticide	50-29-3	8081A
Diallate	semi-volatile	2303-16-4	8270E
Dibenz[a,h]anthracene	PNA	53-70-3	8270E
Debenzofuran	semi-volatile	132-64-9	8270E

CLIENT: GREIF PACKAGING LLC.
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PROJECT: GROUNDWATER MONITORING PROGRAM

ACCEPTABLE ANALYTICAL METHODS
VSWMR TABLE 3.1 (column A + column B)

PARAMETER[1]	CLASS[2]	CAS RN[3]	METHOD[4]
Dibromochloromethane	volatile	124-48-1	8260D
1,2-Dibromo-3-chloropropane (DBCP)	volatile	96-12-8	8011
1,2-Dibromoethane (EDB)	volatile	106-93-4	8011
Di-n-butyl phthalate	semi-volatile	84-74-2	8270E
o-Dichlorobenzene / 1,2-Dichlorobenzene	volatile	95-50-1	8260D
m-Dichlorobenzene / 1,3-Dichlorobenzene	volatile	541-73-1	8260D
p-Dichlorobenzene / 1,4-Dichlorobenzene	volatile	106-46-7	8260D
3,3'-Dichlorobenzidine	semi-volatile	91-94-1	8270E
trans-1,4-Dichloro-2-butene	volatile	110-57-6	8260D
Dichlorodifluoromethane (CFC-12)	volatile	75-71-8	8260D
1,1-Dichloroethane	volatile	75-34-3	8260D
1,2-Dichloroethane (ethylene dichloride)	volatile	107-06-2	8260D
1,1-Dichloroethene	volatile	75-35-4	8260D
cis-1,2-Dichloroethene	volatile	156-59-2	8260D
trans-1,2-Dichloroethene	volatile	156-60-5	8260D
2,4-Dichlorophenol	semi-volatile	120-83-2	8270E
2,6-Dichlorophenol	semi-volatile	87-65-0	8270E
1,2-Dichloropropane	volatile	78-87-5	8260D
1,3-Dichloropropane	volatile	142-28-9	8260D
2,2-Dichloropropane	volatile	594-20-7	8260D
1,1-Dichloropropene	volatile	563-58-6	8260D
cis-1,3-Dichloropropene	volatile	10061-01-5	8260D
trans-1,3-Dichloropropene	volatile	10061-02-6	8260D
Dieldrin	pesticide	60-57-1	8081A
Diethyl phthalate	semi-volatile	84-66-2	8270E
O,O-Diethyl O-2-pyrazinyl	OP pesticide	297-97-2	8270E
Dimethoate	OP pesticide	60-51-5	8270E
p-(Dimethylamino)azobenzene	semi-volatile	60-11-7	8270E
7,12-Dimethylbenzidine[a]anthracene	semi-volatile	57-97-6	8270E
3,3'-Dimethylbenzidine	semi-volatile	119-93-7	8270E
2,4-Dimethylphenol	semi-volatile	105-67-9	8270E
Dimethyl phthalate	semi-volatile	131-11-3	8270E
m-Dinitrobenzene	semi-volatile	99-65-0	8270E

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PROJECT: GROUNDWATER MONITORING PROGRAM

ACCEPTABLE ANALYTICAL METHODS
VSWMR TABLE 3.1 (column A + column B)

PARAMETER[1]	CLASS[2]	CAS RN[3]	METHOD[4]
4,6-Dinitro-o-cresol	semi-volatile	534-52-1	8270E
2,4-Dinitrophenol	semi-volatile	51-28-5	8270E
2,4-Dinitrotoluene	semi-volatile	121-14-2	8270E
2,6-Dinitrotoluene	semi-volatile	606-20-2	8270E
Dinoseb (DNBP)	herbicide	88-85-7	8151A
Di-n-octylphthlate	semi-volatile	117-84-0	8270E
Diphenylamine	semi-volatile	122-39-4	8270E
Disulfoton	OP pesticide	298-04-4	8270E
Endosulfan I	pesticide	959-96-8	8081A
Endosulfan II	pesticide	33213-65-9	8081A
Endosulfan sulfate	pesticide	1031-07-8	8081A
Endrin	pesticide	72-20-8	8081A
Endrin aldehyde	pesticide	7421-93-4	8081A
Ethylbenzene	volatile	100-41-4	8260D
Ethyl methacrylate	volatile	97-63-2	8260D
Ethyl methanesulfonate	semi-volatile	62-50-0	8270E
Famphur	semi-volatile	52-85-7	8270E
Fluoranthene	PNA	206-44-0	8270E
Fluorene	PNA	86-73-7	8270E
Heptachlor	pesticide	76-44-8	8081A
Heptachlor epoxide	pesticide	1024-57-3	8081A
Hexachlorobenzene	semi-volatile	118-74-1	8270E
Hexachlorobutadiene	semi-volatile	87-68-3	8270E
Hexachlorocylopentadiene	semi-volatile	77-47-4	8270E
Hexachloroethane	semi-volatile	67-72-1	8270E
Hexachloropropene	semi-volatile	1888-71-7	8270E
2-Hexanone / Methyl butyl ketone (MBK)	volatile	591-78-6	8260D
Indeno [1,2,3-cd] pyrene	PNA	193-39-5	8270E
Isobutyl alcohol	volatile	78-83-1	8260D
Isodrin	semi-volatile	465-73-6	8270E
Isophorone	semi-volatile	78-59-1	8270E
Isosafrole	semi-volatile	120-58-1	8270E
Kepone	pesticide	143-50-0	8081A

CLIENT: GREIF PACKAGING LLC.
FACILITY: INDUSTRIAL LANDFILL
LOCATION: RIVERVILLE, VIRGINIA
PROJECT: GROUNDWATER MONITORING PROGRAM

ACCEPTABLE ANALYTICAL METHODS
VSWMR TABLE 3.1 (column A + column B)

PARAMETER1	CLASS2	CAS RN3	METHOD4
Lead	metal	Total	6010D
Mercury	volatile metal	Total	SW7470A
Methacrylonitrile	volatile	126-98-7	8260D
Methapyrilene	semi-volatile	91-80-5	8270E
Methoxychlor	pesticide	72-43-5	8081A
Methyl bromide / Bromomethane	volatile	74-83-9	8260D
Methyl chloride / Chloromethane	volatile	74-87-3	8260D
3-Methylcholanthrene	semi-volatile	56-49-5	8270E
Methyl ethyl ketone / 2-Butanone (MEK)	volatile	78-93-3	8260D
Methyl iodide	volatile	74-88-4	8260D
Methyl methacrylate	volatile	80-62-6	8260D
Methyl methanesulfonate	semi-volatile	66-27-3	8270E
2-Methylnaphthalene	semi-volatile	91-57-6	8270E
Methyl parathion	semi-volatile	298-00-0	8270E
4-Methyl-2-pentanone / Methyl isobutyl ketone	volatile	108-10-1	8260D
Methylene bromide / Dibromomethane	volatile	74-95-3	8260D
Methylene chloride / Dichloromethane	volatile	75-09-2	8260D
Naphthalene	volatile	91-20-3	8260D
1,4-Naphthoquinone	semi-volatile	130-15-4	8270E
1-Naphthylamine	semi-volatile	134-32-7	8270E
2-Naphthylamine	semi-volatile	91-59-8	8270E
Nickel	metal	Total	6010D
o-Nitroaniline	semi-volatile	88-74-4	8270E
m-Nitroaniline	semi-volatile	99-09-2	8270E
p-Nitroaniline	semi-volatile	100-01-6	8270E
Nitrobenzene	semi-volatile	98-95-3	8270E
o-Nitrophenol	semi-volatile	88-75-5	8270E
p-Nitrophenol	semi-volatile	100-02-7	8270E
N-Nitrosodi-n-butylamine	semi-volatile	924-16-3	8270E
N-Nitrosodiethylamine	semi-volatile	55-18-5	8270E
N-Nitrosodimethylamine	semi-volatile	62-75-9	8070C
N-Nitrosodiphenylamine	semi-volatile	86-30-6	8270E
N-Nitrosodipropylamine	semi-volatile	621-64-7	8270E

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ACCEPTABLE ANALYTICAL METHODS
VSWMR TABLE 3.1 (column A + column B)

PARAMETER[1]	CLASS[2]	CAS RN[3]	METHOD[4]
N-Nitrosomethylethylamine	semi-volatile	10595-95-6	8270E
N-Nitrosopiperidine	semi-volatile	100-75-4	8270E
N-Nitrosopyrrolidine	semi-volatile	930-55-2	8270E
5-Nitro-o-toluidine	semi-volatile	99-55-8	8270E
Parathion	OP pesticide	56-38-2	8270E
Pentachlorobenzene	semi-volatile	608-93-5	8270E
Pentachloronitrobenzene	semi-volatile	82-68-8	8270E
Pentachlorophenol	semi-volatile	87-86-5	8151A
Phenacetin	semi-volatile	62-44-2	8270E
Phenanthrene	PNA	85-01-8	8270E
Phenol	semi-volatile	108-95-2	8270E
p-Phenylenediamine	semi-volatile	106-50-3	8270E
Phorate	OP pesticide	298-02-2	8270E
Polychlorinated Biphenyls (PCBs)	PCB	See Notes	8081A
Pronamide	semi-volatile	23950-58-5	8270E
Propionitrile	volatile	107-12-0	8260D
Pyrene	PNA	129-00-0	8270E
Safrole	semi-volatile	94-59-7	8270E
Selenium	metal	Total	6020B
Silver	metal	Total	6020B
Silvex (2,4,5-TP)	herbicide	93-72-1	8151A
Styrene	volatile	100-42-5	8260D
Sulfide		18496-25-8	9030
2,4,5-Trichlorophenoxyacetic acid (2,4,5-T)	herbicide	93-76-5	8151A
1,2,4,5-Tetrachlorobenzene	semi-volatile	95-94-3	8270E
1,1,1,2-Tetrachloroethane	volatile	630-20-6	8260D
1,1,2,2-Tetrachloroethane	volatile	79-34-5	8260D
Tetrachloroethene (PCE)	volatile	127-18-4	8260D
2,3,4,6-Tetrachlorophenol	semi-volatile	58-90-2	8270E
Thallium	metal	Total	6020B
Tin	metal	Total	6010D
Toluene	volatile	108-88-3	8260D
o-Toluidine	semi-volatile	95-53-4	8270E

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ACCEPTABLE ANALYTICAL METHODS
VSWMR TABLE 3.1 (column A + column B)

PARAMETER[1]	CLASS[2]	CAS RN[3]	METHOD[4]
Toxaphene	pesticide	See Notes	8081A
1,2,4-Trichlorobenzene	volatile	120-82-1	8260D
1,1,1-Trichloroethane	volatile	71-55-6	8260D
1,1,2-Trichloroethane	volatile	79-00-5	8260D
Trichloroethene	volatile	79-01-6	8260D
Trichlorofluoromethane (CFC-11)	volatile	75-69-4	8260D
2,4,5-Trichlorophenol	semi-volatile	95-95-4	8270E
2,4,6-Trichlorophenol	semi-volatile	88-06-2	8270E
1,2,3-Trichloropropane	volatile	96-18-4	8260D
O,O,O-Triethyl phosphorothioate	semi-volatile	126-68-1	8270E
syn-Trinitrobenzene	semi-volatile	99-35-4	8270E
Vanadium	metal	Total	6010D
Vinyl acetate	volatile	108-05-4	8260D
Vinyl chloride	volatile	75-01-4	8021
Xylene (total)	volatile	See Notes	8260D
Zinc	metal	Total	6010D

NOTES PERTAINING TO COLUMN LABELS

1- PARAMETER. Common name of parameter.

2- CLASS. General type of compound.

3- CAS RN. Chemical Abstracts Service Registry Number. Where "Total" is entered (metals), all species in the groundwater that contain this element are included.

4- METHOD. Analytical method. EPA SW-846. Test Methods for Evaluating Solid Waste: Physical/Chemical Methods.

NOTES PERTAINING TO TABLE FORMATTING

Constituents shown in bold (red) font are those listed in VSWMR Table 3.1 Column A.

NOTES PERTAINING TO INDIVIDUAL CONSTITUENTS

Bis (2-chloro-1-methylethyl) ether. This substance is often called Bis(2-chloroisopropyl) ether, the name that CAS applies to its noncommercial isomer, Propane, 2,2'-oxybis(2-chloro-) (CAS RN 39638-32-9).

Chlordane. This entry includes alpha-chlordane (CAS RN 5103-71-9), beta-chlordane (CAS RN 5103-74-2), gamma-chlordane (CAS RN 5566-34-7), and constituents of chlordane (CAS RN 57-74-9 and CAS RN 12672-29-6).

Isobutyl alcohol. A PQL value for Method 8260 has not yet been published in SW-846.

Kepone. DEQ Appendix 5.1 lists method 8270 (GCMS), but not method 8080 (GC); however, it is believed that the extraction process used in method 8270 degrades kepone, such that method 8080 is here preferred.

N-Nitrosodimethylamine. A PQL value for Method 8260 has not yet been published in SW-846.

Polychlorinated biphenyls. (CAS RN 1336-36-3) This category contains congener chemicals, including constituents of Aroclor 1016 (CAS RN 12674-11-2), Arochlor 1221 (CAS RN 11104-28-2), Aroclor 1232 (CAS RN 11141-16-5), Aroclor 1242 (CAS RN 53469-21-9), Arochlor 1248 (CAS RN 12672-29-6), Aroclor 1254 (CAS RN 11097-69-1), and Aroclor 1260 (CAS RN 11096-82-5). The PQL may represent an average value for PCB congeners.

Tin. DEQ Appendix 5.1 lists only method 6010 (ICP), and not method 7871 (furnace); however, the latter is here preferred.

Toxaphene. This entry includes congener chemicals contains in technical toxaphene (CAS RN 8001-35-2), such as chlorinated camphene.

Xylene (total). This entry includes o-xylene, m-xylene, p-xylene, and unspecified xylenes (dimethylbenzenes) (CAS RN 1330-20-7).

APPENDIX 3

GROUNDWATER PROTECTION STANDARDS

CLIENT: GREIF PACKAGING LLC
FACILITY: INDUSTRIAL LANDFILL
LOCATION: RIVERVILLE, AMHERST COUNTY, VIRGINIA
PROJECT: GROUNDWATER MONITORING PLAN

GROUNDWATER PROTECTION STANDARDS
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PARAMETER[1]	CLASS[2]	CAS RN[3]	SPL[4] (µg/L)	MCL[5] (µg/L)	[E^{-6}] ACL[6] (µg/L)	GWPS[7] (µg/L)
Acenaphthene	semi-volatile	83-32-9	-	-	530	ACL
Acenaphthylene	semi-volatile	208-96-8	-	-	none	LOQ
Acetone	volatile	67-64-1	-	-	14000	ACL
Acetophenone	semi-volatile	98-86-2	-	-	1900	ACL
Acetonitrile (methyl cyanide)	volatile	75-05-8	-	-	130	ACL
2-Acetylaminofluorene	semi-volatile	53-96-3	-	-	0.016	ACL
Acrolein	volatile	107-02-8	-	-	0.042	ACL
Acrylonitrile	volatile	107-13-1	-	-	0.052	ACL
Aldrin	pesticide	309-00-2	-	-	0.00092	ACL
Allyl chloride	volatile	107-05-1	-	-	0.73	ACL
4-Aminobiphenyl	semi-volatile	92-67-1	-	-	0.003	ACL
Anthracene	PNA	120-12-7	-	-	1800	ACL
Antimony	metal	Total	18.8	6	7.8	SPL
Arsenic	metal	Total	-	10	0.052	MCL
Barium	metal	Total	1313	2000	3800	MCL
Benzene	volatile	71-43-2	-	5	0.46	MCL
Benzo[a]anthracene	PNA	56-55-3	-	-	0.03	ACL
Benzo[b]fluoranthene	PNA	205-99-2	-	-	0.25	ACL
Benzo[k]fluoranthene	PNA	207-08-9	-	-	2.5	ACL
Benzo[ghi]perylene	PNA	191-24-2	-	-	none	LOQ
Benzo[a]pyrene	PNA	50-32-8	-	0.2	0.025	MCL
Benzyl alcohol	semi-volatile	100-51-6	-	-	2000	ACL
Beryllium	metal	Total	-	4	25	MCL
alpha-BHC	pesticide	319-84-6	-	-	0.0072	ACL
beta-BHC	pesticide	319-85-7	-	-	0.025	ACL
delta-BHC	pesticide	319-86-8	-	-	none	LOQ
gamma-BHC(Lindane)	pesticide	58-89-9	-	0.2	0.042	MCL
Bis (2-chloroethoxy) methane	semi-volatile	111-91-1	-	-	59	ACL
Bis (2-chloroethyl) ether	semi-volatile	111-44-4	-	-	0.014	ACL
Bis (2-chloro-1-methylethyl) ether ♣	semi-volatile	108-60-1	-	-	710	ACL
Bis (2-ethylhexyl) phthalate / di(2-ethylhexyl)phthalate	semi-volatile	117-81-7	-	6	5.6	MCL
Bromochloromethane	volatile	74-97-5	-	-	83	ACL
Bromodichloromethane ♣	volatile	75-27-4	-	Σ 80	0.13	MCL
Bromoform ♣ [tribromomethane]	volatile	75-25-2	-	Σ 80	3.3	MCL
4-Bromophenyl phenyl ether	semi-volatile	101-55-3	-	-	none	LOQ
Butyl benzyl phthalate	semi-volatile	85-68-7	-	-	16	ACL
Cadmium	metal	Total	11.1	5	9.2	SPL
Carbon disulfide	volatile	75-15-0	-	-	810	ACL

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PARAMETER$_1$	CLASS$_2$	CAS RN$_3$	SPL$_4$ (µg/L)	MCL$_5$ (µg/L)	[E^{-6}] ACL$_6$ (µg/L)	GWPS$_7$ (µg/L)
Carbon tetrachloride	volatile	56-23-5	-	5	0.46	MCL
Chlordane ♣	pesticide		-	2	0.02	MCL
p-Chloroaniline	semi-volatile	106-47-8	-	-	0.37	ACL
Chlorobenzene / monochlorobenzene	volatile	108-90-7	-	100	78	MCL
Chlorobenzilate	semi-volatile	510-15-6	-	-	0.31	ACL
p-Chloro-m-cresol	semi-volatile	59-50-7	-	-	1400	ACL
Chloroethane	volatile	75-00-3	-	-	21000	ACL
Chloroform ♣ (trichloromethane)	volatile	67-66-3	-	Σ 80	0.22	MCL
2-Chloronaphthalene	semi-volatile	91-58-7	-	-	750	ACL
2-Chlorophenol	semi-volatile	95-57-8	-	-	91	ACL
4-Chlorophenyl phenyl ether	semi-volatile	7005-72-3	-	-	none	LOQ
Chloroprene	volatile	126-99-8	-	-	0.019	ACL
Chromium (all valence states)	metal	Total	127.67	100	none	SPL
Chrysene	PNA	218-01-9	-	-	25	ACL
Cobalt	metal	Total	140.9	-	6	SPL
Copper	metal	Total	270.7	1300	800	MCL
m-Cresol	semi-volatile	108-39-4	-	-	930	ACL
o-Cresol	semi-volatile	95-48-7	-	-	930	ACL
p-Cresol	semi-volatile	106-44-5	-	-	1900	ACL
Cyanide (free)		57-12-5	-	200	1.5	MCL
2,4-Dichlorophenoxyacetic acid (2,4-D)	herbicide	94-75-7	-	70	170	MCL
4,4'-DDD	pesticide	72-54-8	-	-	0.032	ACL
4,4'-DDE	pesticide	72-55-9	-	-	0.046	ACL
4-4'-DDT	pesticide	50-29-3	-	-	0.23	ACL
Diallate	semi-volatile	2303-16-4	-	-	0.54	ACL
Dibenz[a,h]anthracene	PNA	53-70-3	-	-	0.025	ACL
Dibenzofuran	semi-volatile	132-64-9	-	-	7.9	ACL
Dibromochloromethane ♣	volatile	124-48-1	-	Σ 80	0.87	MCL
1,2-Dibromo-3-chloropropane (DBCP)	volatile	96-12-8	-	0.2	0.00033	MCL
1,2-Dibromoethane (EDB)	volatile	106-93-4	-	0.05	0.0075	MCL
Di-n-butyl phthalate	semi-volatile	84-74-2	-	-	900	ACL
Di-n-octylphthalate	semi-volatile	117-84-0	-	-	200	ACL
o-Dichlorobenzene / 1,2-Dichlorobenzene	volatile	95-50-1	-	600	300	MCL
m-Dichlorobenzene / 1,3-Dichlorobenzene	volatile	541-73-1	-	-	none	LOQ
p-Dichlorobenzene / 1,4-Dichlorobenzene	volatile	106-46-7	-	75	0.48	MCL
3,3'-Dichlorobenzidine	semi-volatile	91-94-1	-	-	0.13	ACL
trans-1,4-Dichloro-2-butene	volatile	110-57-6	-	-	0.0013	ACL
Dichlorodifluoromethane (CFC-12)	volatile	75-71-8	-	-	200	ACL

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PARAMETER[1]	CLASS[2]	CAS RN[3]	SPL[4] (µg/L)	MCL[5] (µg/L)	[E^{-6}] ACL[6] (µg/L)	GWPS[7] (µg/L)
1,1-Dichloroethane	volatile	75-34-3	-	-	2.8	ACL
1,2-Dichloroethane (ethylene dichloride)	volatile	107-06-2	-	5	0.17	MCL
1,1-Dichloroethene	volatile	75-35-4	-	7	280	MCL
cis-1,2-Dichloroethene	volatile	156-59-2	-	70	36	MCL
trans-1,2-Dichloroethene	volatile	156-60-5	-	100	360	MCL
2,4-Dichlorophenol	semi-volatile	120-83-2	-	-	46	ACL
2,6-Dichlorophenol	semi-volatile	87-65-0	-	-	none	LOQ
1,2-Dichloropropane	volatile	78-87-5	-	5	0.85	MCL
1,3-Dichloropropane	volatile	142-28-9	-	-	370	ACL
2,2-Dichloropropane	volatile	594-20-7	-	-	none	LOQ
1,1-Dichloropropene	volatile	563-58-6	-	-	none	LOQ
cis-1,3-Dichloropropene	volatile	10061-01-5	-	-	none	LOQ
trans-1,3-Dichloropropene	volatile	10061-02-6	-	-	none	LOQ
Dieldrin	pesticide	60-57-1	-	-	0.0018	ACL
Diethyl phthalate	semi-volatile	84-66-2	-	-	15000	ACL
O,O-Diethyl O-2-pyrazinyl	OP pesticide	297-97-2	-	-	none	LOQ
Dimethoate	OP pesticide	60-51-5	-	-	44	ACL
p-(Dimethylamino)azobenzene	semi-volatile	60-11-7	-	-	0.005	ACL
7,12-Dimethylbenzidine[a]anthracene	semi-volatile	57-97-6	-	-	0.0001	LOQ
3,3'-Dimethylbenzidine	semi-volatile	119-93-7	-	-	0.0065	ACL
2,4-Dimethylphenol	semi-volatile	105-67-9	-	-	360	ACL
Dimethyl phthalate	semi-volatile	131-11-3	-	-	none	LOQ
m-Dinitrobenzene	semi-volatile	99-65-0	-	-	2	ACL
4,6-Dinitro-o-cresol	semi-volatile	534-52-1	-	-	1.5	ACL
2,4-Dinitrophenol	semi-volatile	51-28-5	-	-	39	ACL
2,4-Dinitrotoluene	semi-volatile	121-14-2	-	-	0.24	ACL
2,6-Dinitrotoluene	semi-volatile	606-20-2	-	-	0.049	ACL
Dinoseb (DNBP)	herbicide	88-85-7	-	7	15	MCL
Diphenylamine	semi-volatile	122-39-4	-	-	1300	ACL
Disulfoton	OP pesticide	298-04-4	-	-	0.5	ACL
Endosulfan	pesticide	115-29-7	-	-	100	ACL
Endosulfan I	pesticide	959-96-8	-	-	none	LOQ
Endosulfan II	pesticide	33213-65-9	-	-	none	LOQ
Endosulfan sulfate	pesticide	1031-07-8	-	-	none	LOQ
Endrin	pesticide	72-20-8	-	2	2.3	MCL
Endrin aldehyde	pesticide	7421-93-4	-	-	none	LOQ
Ethylbenzene	volatile	100-41-4	-	700	1.5	MCL
Ethyl methacrylate	volatile	97-63-2	-	-	630	ACL

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PARAMETER[1]	CLASS[2]	CAS RN[3]	SPL_4 (µg/L)	MCL_5 (µg/L)	[E^{-6}] ACL_6 (µg/L)	$GWPS_7$ (µg/L)
Ethyl methanesulfonate	semi-volatile	62-50-0	-	-	none	LOQ
Famphur	semi-volatile	52-85-7	-	-	none	LOQ
Fluoranthene	PNA	206-44-0	-	-	800	ACL
Fluorene	PNA	86-73-7	-	-	290	ACL
Heptachlor	pesticide	76-44-8	-	0.4	0.0014	MCL
Heptachlor epoxide	pesticide	1024-57-3	-	0.2	0.0014	MCL
Hexachlorobenzene	semi-volatile	118-74-1	-	1	0.0098	MCL
Hexachlorobutadiene	semi-volatile	87-68-3	-	-	0.14	ACL
Hexachlorocyclopentadiene	semi-volatile	77-47-4	-	50	0.41	MCL
Hexachloroethane	semi-volatile	67-72-1	-	-	0.33	ACL
Hexachloropropene	semi-volatile	1888-71-7	-	-	none	LOQ
2-Hexanone / Methyl butyl ketone (MBK)	volatile	591-78-6	-	-	38	ACL
Indeno [1,2,3-cd] pyrene	PNA	193-39-5	-	-	0.25	ACL
Isobutyl alcohol	volatile	78-83-1	-	-	5900	ACL
Isodrin	semi-volatile	465-73-6	-	-	none	LOQ
Isophorone	semi-volatile	78-59-1	-	-	78	ACL
Isosafrole	semi-volatile	120-58-1	-	-	none	LOQ
Kepone	pesticide	143-50-0	-	-	0.0035	ACL
Lead ♣	metal	Total	-	15	none	MCL
Mercury	volatile metal	Total	-	2	0.63	MCL
Methacrylonitrile	volatile	126-98-7	-	-	1.9	ACL
Methapyrilene	semi-volatile	91-80-5	-	-	none	LOQ
Methoxychlor	pesticide	72-43-5	-	40	37	MCL
Methyl bromide / Bromomethane	volatile	74-83-9	-	-	7.5	ACL
Methyl chloride / Chloromethane	volatile	74-87-3	-	-	190	ACL
3-Methylcholanthrene	semi-volatile	56-49-5	-	-	0.0011	ACL
Methylene bromide / Dibromomethane	volatile	74-95-3	-	-	8.3	ACL
Methylene chloride / Dichloromethane	volatile	75-09-2	-	5	11	MCL
Methyl ethyl ketone / 2-Butanone (MEK)	volatile	78-93-3	-	-	5600	ACL
Methyl iodide	volatile	74-88-4	-	-	none	LOQ
Methyl methacrylate	volatile	80-62-6	-	-	1400	ACL
Methyl methanesulfonate	semi-volatile	66-27-3	-	-	0.79	ACL
2-Methylnaphthalene	semi-volatile	91-57-6	-	-	36	ACL
Methyl parathion	semi-volatile	298-00-0	-	-	4.5	ACL
4-Methyl-2-pentanone / Methyl isobutyl ketone	volatile	108-10-1	-	-	6300	ACL
Naphthalene	volatile	91-20-3	-	-	0.12	ACL
1,4-Naphthoquinone	semi-volatile	130-15-4	-	-	none	LOQ
1-Naphthylamine	semi-volatile	134-32-7	-	-	none	LOQ

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EFFECTIVE 01-18-21

PARAMETER$_1$	CLASS$_2$	CAS RN$_3$	SPL$_4$ (µg/L)	MCL$_5$ (µg/L)	[E^{-6}] ACL$_6$ (µg/L)	GWPS$_7$ (µg/L)
2-Naphthylamine	semi-volatile	91-59-8	-	-	0.039	ACL
Nickel	metal	Total	125.6	-	390	ACL
o-Nitroaniline / 2-	semi-volatile	88-74-4	-	-	190	ACL
m-Nitroaniline / 3-	semi-volatile	99-09-2	-	-	none	LOQ
p-Nitroaniline / 4-	semi-volatile	100-01-6	-	-	3.8	ACL
Nitrobenzene	semi-volatile	98-95-3	-	-	0.14	ACL
o-Nitrophenol	semi-volatile	88-75-5	-	-	none	LOQ
p-Nitrophenol	semi-volatile	100-02-7	-	-	none	LOQ
N-Nitrosodi-n-butylamine	semi-volatile	924-16-3	-	-	0.0027	ACL
N-Nitrosodiethylamine	semi-volatile	55-18-5	-	-	0.00017	ACL
N-Nitrosodimethylamine	semi-volatile	62-75-9	-	-	0.00011	ACL
N-Nitrosodiphenylamine	semi-volatile	86-30-6	-	-	12	ACL
N-Nitrosodi-n-propylamine	semi-volatile	621-64-7	-	-	0.011	ACL
N-Nitrosomethylethylamine	semi-volatile	10595-95-6	-	-	0.00071	ACL
N-Nitrosopiperidine	semi-volatile	100-75-4	-	-	0.0082	ACL
N-Nitrosopyrrolidine	semi-volatile	930-55-2	-	-	0.037	ACL
5-Nitro-o-toluidine	semi-volatile	99-55-8	-	-	8.2	ACL
Parathion	OP pesticide	56-38-2	-	-	86	ACL
Polychlorinated Biphenyls (PCBs) ♣	PCB		-	0.5	0.044	MCL
Pentachlorobenzene	semi-volatile	608-93-5	-	-	3.2	ACL
Pentachloronitrobenzene	semi-volatile	82-68-8	-	-	0.12	ACL
Pentachlorophenol	semi-volatile	87-86-5	-	1	0.041	MCL
Phenacetin	semi-volatile	62-44-2	-	-	34	ACL
Phenanthrene	PNA	85-01-8	-	-	none	LOQ
Phenol	semi-volatile	108-95-2	-	-	5800	ACL
p-Phenylenediamine	semi-volatile	106-50-3	-	-	20	ACL
Phorate	OP pesticide	298-02-2	-	-	3	ACL
Pronamide	semi-volatile	23950-58-5	-	-	1200	ACL
Propionitrile	volatile	107-12-0	-	-	none	LOQ
Pyrene	PNA	129-00-0	-	-	120	ACL
Safrole	semi-volatile	94-59-7	-	-	0.096	ACL
Selenium	metal	Total	-	50	100	MCL
Silver	metal	Total	-	-	94	ACL
Silvex (2,4,5-TP)	herbicide	93-72-1	-	50	110	MCL
Styrene	volatile	100-42-5	-	100	1200	MCL
Sulfide		18496-25-8	-	-	none	LOQ
1,2,4,5-Tetrachlorobenzene	semi-volatile	95-94-3	-	-	1.7	ACL
1,1,1,2-Tetrachloroethane	volatile	630-20-6	-	-	0.57	ACL

CLIENT: GREIF PACKAGING LLC
FACILITY: INDUSTRIAL LANDFILL
LOCATION: RIVERVILLE, AMHERST COUNTY, VIRGINIA
PROJECT: GROUNDWATER MONITORING PLAN

GROUNDWATER PROTECTION STANDARDS
EFFECTIVE 01-18-21

PARAMETER$_1$	CLASS$_2$	CAS RN$_3$	SPL$_4$ (µg/L)	MCL$_5$ (µg/L)	[E^{-6}] ACL$_6$ (µg/L)	GWPS$_7$ (µg/L)
1,1,2,2-Tetrachloroethane	volatile	79-34-5	-	-	0.076	ACL
Tetrachloroethene (PCE)	volatile	127-18-4	-	5	11	MCL
2,3,4,6-Tetrachlorophenol	semi-volatile	58-90-2	-	-	240	ACL
Thallium	metal	Total	-	2	0.2	MCL
Tin	metal	Total	-	-	12000	ACL
Toluene	volatile	108-88-3	-	1000	1100	MCL
o-Toluidine	semi-volatile	95-53-4	-	-	none	LOQ
Toxaphene ♣	pesticide		-	3	0.071	MCL
1,2,4-Trichlorobenzene	volatile	120-82-1	-	70	1.2	MCL
1,1,1-Trichloroethane	volatile	71-55-6	-	200	8000	MCL
1,1,2-Trichloroethane	volatile	79-00-5	-	5	0.28	MCL
Trichloroethene	volatile	79-01-6	-	5	0.49	MCL
Trichlorofluoromethane (CFC-11)	volatile	75-69-4	-	-	5200	ACL
2,4,5-Trichlorophenol	semi-volatile	95-95-4	-	-	1200	ACL
2,4,6-Trichlorophenol	semi-volatile	88-06-2	-	-	4.1	ACL
2,4,5-Trichlorophenoxyacetic acid (2,4,5-T)	herbicide	93-76-5	-	-	160	ACL
1,2,3-Trichloropropane	volatile	96-18-4	-	-	0.00075	ACL
O,O,O-Triethyl phosphorothioate	semi-volatile	126-68-1	-	-	none	LOQ
syn-Trinitrobenzene / 1,3,5-	semi-volatile	99-35-4	-	-	590	ACL
Vanadium	metal	Total	442	-	86	SPL
Vinyl acetate	volatile	108-05-4	-	-	410	ACL
Vinyl chloride	volatile	75-01-4	-	2	0.019	MCL
Xylene (total) ♣	volatile		-	10000	190	MCL
Zinc	metal	Total	628	-	6000	ACL

♣ – see NOTES

NOTES PERTAINING TO COLUMN LABELS

1- PARAMETER. Common name of parameter.

2- CLASS. General type of compound.

3- CAS RN. Chemical Abstracts Service Registry Number. Where "Total" is entered (metals), all species in the groundwater that contain this element are included.

4- SPL. Statistical prediction limit. Upper prediction limit based on statistical analyses when a constituent is observed in the upgradient well(s).

5- MCL. Maximum Contamination Level. EPA Drinking Water Standard, current standards. Subject to change without notice as directed by DEQ.

6- ACL. Alternate concentration limit. A risk based standard developed by the DEQ for constituents without an MCL. Subject to change without notice as directed by DEQ. [E^{-6}] - carcinogenic risk level (default)

7- Selected GWPS. Selected Groundwater Protection Standard. A Groundwater Protection Standard represents the largest concentration of a constituent that may be observed in any downgradient well that will not trigger Corrective Action.

NOTES PERTAINING TO TABLE FORMATTING

Constituents shown in bold (red) font are those listed in VSWMR Table 3.1 Column A.

(0) - Indicates constituents with no established ACL. The laboratory Limit of Quantitation serves as the "ACL".

♣ NOTES PERTAINING TO INDIVIDUAL CONSTITUENTS ♣

Bis (2-chloro-1-methylethyl) ether. This substance is often called Bis(2-chloroisopropyl) ether, the name that CAS applies to its noncommercial isomer, Propane, 2,2'-oxybis(2-chloro-) (CAS RN 39638-32-9).

Bromoform. Trihalomethane constituents have a cumulative MCL of 80 μ g/liter.

Bromodichloromethane. Trihalomethane constituents have a cumulative MCL of 80 μ g/liter.

Chlordane. This entry includes alpha-chlordane (CAS RN 5103-71-9), beta-chlordane (CAS RN 5103-74-2), gamma-chlordane (CAS RN 5566-34-7), and constituents of chlordane (CAS RN 57-74-9 and CAS RN 12672-29-6).

Chloroform. Trihalomethane constituents have a cumulative MCL of 80 μ g/liter.

Dibromochloromethane. Trihalomethane constituents have a cumulative MCL of 80 μ g/liter.

Lead. Posted MCL represents an EPA action level. Prior MCL was 50 μ g/liter.

Polychlorinated biphenyls. (CAS RN 1336-36-3) This category contains congener chemicals, including constituents of Aroclor 1016 (CAS RN 12674-11-2), Arochlor 1221 (CAS RN 11104-28-2), Aroclor 1232 (CAS RN 11141-16-5), Aroclor 1242 (CAS RN 53469-21-9), Arochlor 1248 (CAS RN 12672-29-6), Aroclor 1254 (CAS RN 11097-69-1), and Aroclor 1260 (CAS RN 11096-82-5). The PQL may represent an average value for PCB congeners.

Toxaphene. This entry includes congener chemicals contains in technical toxaphene (CAS RN 8001-35-2), such as chlorinated camphene.

Xylene (total). This entry includes o-xylene, m-xylene, p-xylene, and unspecified xylenes (dimethylbenzenes) (CAS RN 1330-20-7).

APPENDIX 4

SPECIFICATIONS:

DRILLING AND WELL CONSTRUCTION

SPECIFICATIONS:

DRILLING AND WELL CONSTRUCTION

All groundwater monitoring wells shall meet State requirements, as applicable.

1.0 DRILLING

Information concerning drilling methods is provided in this section.

1.1 Nominal Boring Diameter

In all cases where the diameter of the wellpipe shall be 2 inches, the minimum nominal borehole diameter of borings advanced through soil materials shall be 6 inches, in order to the help ensure that the minimum width of the annulus around the wellpipe shall be 2 inches.

1.2 Drilling Methods

Borings may be advanced by hollow stem auger, wash or air rotary and/or coring methods.

1.3 Cuttings

Drilling shall be performed in a manner that minimizes the spreading of soil cuttings. All cuttings shall be stockpiled so that a representative composite sample can be obtained to determine if any contamination is present. Disposition of cuttings upon project completion shall be the responsibility of Facility or the Facility's designated representative.

2.0 SOIL AND ROCK SAMPLING

Information concerning methods of sampling soil and rock is provided in this section.

2.1 Split Spoon Sampling

During hollow stem auger drilling, soil materials shall be sampled using split-spoon samplers or liners (typically associated with direct push methods).

At a minimum, soil samples shall be collected at 5.0 foot intervals between 5 feet below the surface of the ground and the bottom of the borehole.

At clustered well locations, sampling of deeper wells need not begin until reaching 5 feet below the depth of an adjacent, shallower well.

Each well and/or piezometer shall be installed in a separate borehole. No two wells or piezometers shall be installed (nested) in the same borehole.

2.2 Cuttings

During drilling, the driller shall provide cuttings at intervals specified by the Facility or the Facility's representative. The driller shall keep cuttings clear of the borehole.

2.3 Continuous Coring

During rotary drilling of bedrock, the driller shall perform continuous coring as requested by the Facility or Facility's representative.

2.4 Sample Disposition

Disposition of sample material upon completion of the project shall be handled with the drill cuttings.

3.0 WELL CONSTRUCTION

Information concerning specifications for well construction is provided in this section.

3.1 Construction Method

In the event that the borehole stands open, the augers may be removed prior to installing the well. In the event that the borehole fails upon removal of the augers, then the well shall be constructed within the augers. In the event that the hole fails and the auger is too small to permit tremie pipe construction, then the boring shall be re-drilled with a larger augers, and the well shall be constructed within those augers.

3.2 Wellpipe and Screen

Each monitoring well shall be constructed of pre-cleaned, flush-threaded Schedule 40 PVC pipe having an inner diameter of 2 inches.

The base of each well shall terminate with a screen 10 feet in length. Screen shall be factory-slotted. Slots shall be 0.01 inch in width.

The driller shall wear clean surgical-type gloves when handling PVC wellpipe, and the pipe shall be maintained in a clean manner.

In order to provide a clean cut, a PVC pipe-cutter should be used whenever it is necessary to shorten sections of the PVC wellpipe: a hacksaw should not be used.

3.3 Sandpack

The sandpack shall be a clean sand of proper size in relation to the screen slots to prevent its passage into the well, with no fraction coarser than 0.25 inch nominal diameter.

The sandpack shall be placed in the annulus around the well riser and to a point approximately 2 feet above the top of the screen. A tremie pipe shall be used as feasible.

3.4 Bentonite Seal

The annulus around the wellpipe shall be sealed with a layer of bentonite pellets, to be placed directly above the sandpack. The minimum thickness of the bentonite layer shall be approximately two (2) feet. The bentonite pellets shall be allowed a minimum time of 24 hours for hydration prior to continuing with well construction. A tremie pipe shall be used as feasible.

3.5 Grout

Following hydration of the bentonite seal, each boring shall be sealed with a Portland Type I cement/bentonite slurry, using the tremie-pipe method.

Bentonite content in the slurry shall be approximately 2 to 5 percent by weight to the help reduce shrinkage. When feasible, the hollow stem auger should be used as a temporary casing while placing the sandpack, bentonite seal, and cement-bentonite backfill.

3.6 Surface Completion

The driller shall be prepared for either manhole or stickup surface completions.

Manhole installations. In the case of manhole installations, suitable surface completion shall consist of capped PVC riser and steel manhole.

> The PVC riser shall be provided with a lockable, water-tight, expansion cap. The driller shall provide a lock for each cap. All locks shall be keyed identically and all keys relinquished to the facility/facility's representative.
>
> The manhole shall be placed in a manner that permits surface water to drain away from the manhole cover.

Stickup installations. In the case of stickup installations, suitable surface completion shall consist of a concrete apron, capped PVC well riser, and outer protective casing.

The concrete apron shall have the following minimum dimensions: 2 feet x 2 feet x 3.5 inches, and shall be centered with respect to the riser. A form shall be used in constructing the apron. The form should be centered with respect to the PVC riser. The upper surface of the apron should be graded to provide drainage away from the PVC riser. A monument shall be set into the pad for surveying purposes.

The inner PVC riser (wellpipe) shall extend to an approximate the height of between 18 inches and 24 inches above the top of the concrete pad. A vent hole having a diameter of 0.25 inches shall be drilled through the PVC riser at a point 2 inches below its top. Shavings generated by drilling the PVC riser shall be prevented from falling into the well. The PVC riser shall be provided with a slip-on PVC cap.

The outer protective casing shall be constructed of steel or aluminum pipe having a diameter, or diagonal, of not less than 6 inches. The top of the outer protective casing, when uncovered, should be placed at a point between 0.5 inches above the top of the PVC wellpipe and 0.5 inches below the top of the PVC pipe. A drain hole having a diameter of 0.5 inches shall be drilled through the outer protective casing near the top of the concrete apron.

The outer protective casing shall be lockable. The well will be locked before leaving the site.

4.0 SURVEYING

Information concerning requirements for surveying is provided in this section.

Well elevations shall be surveyed to mean sea level or established local datum by a licensed surveyor. Survey points shall include:

- top of outer protective steel casing (when closed)
- inner PVC wellpipe
- concrete pad (on monument)
- ground surface (not marked).

Horizontal location of the surveyed points shall be measured to the nearest 0.1 foot.

Elevation of outer casing, well pipe, and concrete pad shall be measured to the nearest 0.01 foot.

5.0 WELL DEVELOPMENT AND INSPECTION

Information concerning post construction activities is provided in this section.

Wells will be developed in order to achieve a substantial reduction in turbidity.

Development shall be conducted by pumping or bailing. When practicable, a surge block may be used as a means of enhancing the development process.

In the event a pump is employed, the design of the pump shall be such that groundwater having contact with air is not allowed to drain back into the well. Air surging shall not be used.

All well development equipment (bailers, pumps, surge blocks), and any additional equipment, that contacts subsurface formations shall be decontaminated prior to on-site use, between consecutive on-site uses, and/or between consecutive well installations, as directed by Facility or Facility's designated representative.

6.0 ANCILLARY REQUIREMENTS

Ancillary requirements are provided in this section.

6.1 Extraneous Material

The driller shall take all reasonable care to ensure that each boring is free from all materials other than those required for well construction. "Materials required for well construction" is the here defined to include polyvinyl chloride (PVC), sand, bentonite, Portland cement, and natural soil materials.

All other materials accidentally or purposely placed in the hole shall be removed by driller prior to well completion.

6.2 Decontamination

All drilling equipment (drillsteel, bits, casing materials), and any additional equipment, that contacts subsurface formations shall be decontaminated prior to on-site use, between consecutive on-site uses, and/or between consecutive well installations, as directed by facility or facility's designated representative.

Appropriate decontamination procedure may consist of steam cleaning with potable water and biodegradable detergent (e.g., Liquinox) approved by facility or facility's designated representative. Steam cleaning shall be conducted in a manner that minimizes over-spray and runoff.

6.3 Disposition of Wastewater

All drilling contamination fluids and well development wastewater shall be discharged to the on-site wastewater treatment facility.

6.4 Site Safety Plan

The driller is responsible for maintaining the personal safety of his employees while on site. The driller shall keep a fire extinguisher (in good working condition) and first aid kit at the site at all times during which the site is occupied by his employees.

The driller shall be responsible for providing any personal protective equipment that might be required by **OSHA** and other agencies, including, but not necessarily limited to, hard hats, the hearing protection, and steel-toed boots, for all personnel employed by the driller.

Use of tobacco at the facility is prohibited.

6.5 Cleanup

After completing construction of a well, all refuse will be removed from the well site. Such refuse typically includes, but is not limited to, PVC pipe wrappers, sandbags, bentonite bags, cement bags, beverage containers, food wrappers, and other forms of litter.

6.6 Documentation

Upon completion of well construction, the following information shall be provided in a form suitable for submission to the Director of Environmental Quality:

- date of construction,
- drilling method and fluid used (if applicable),
- boring diameter,
- wellpipe (inner casing) specifications,
- well depth (+/- 0.01 ft),
- drilling/lithologic logs,
- specifications for other casing materials (if applicable),
- screen specifications,
- wellpipe/screen joint type,
- sandpack specifications (material, size),
- amount of sandpack,
- sandpack placement methods,
- bentonite seal specifications,
- amount of bentonite seal,
- bentonite seal placement method,
- grout specifications,
- amount of grout,
- grout placement method,
- surface completion specifications,
- well development procedure,
- surveyed well location (within +/- 0.5 ft),
- surveyed well elevations (+/- 0.01 ft).

Within 30 days of installation, a boring log (certified by a qualified groundwater scientist) shall be prepared and submitted to DEQ for each newly constructed monitoring well describing the soils encountered, the hydraulic conductivity of the geologic units (formations) encountered, the total depth of the monitoring well, location of the screened interval, the top and bottom of sandpack, and the top and bottom of the seal.

A copy of the final log, including a site plan showing the location of all monitoring wells, shall be submitted to DEQ within ***14 days*** (***44 days*** of well construction date) of completing the well certification.

7.0 WELL ABANDONMENT

Information concerning procedures for abandoning boreholes and wells is provided in this section.

All drilled borings that are not used for well construction shall be abandoned as early as is feasible after drilling has been completed. Such borings shall be abandoned by filling the borehole with a cement-bentonite grout or with bentonite pellets.

Wells shall be abandoned by either (1) re-drilling the boring and filling the open borehole with a cement-bentonite grout or bentonite pellets or (2) filling the wellpipe with a cement-bentonite grout or bentonite pellets.

- When the borehole or well pipe is backfilled with grout, the bentonite content of the cement-bentonite grout shall be 5% or more. A tremie pipe may be used to the help ensure that the grout is continuously placed from the bottom of the borehole/pipe upward.

- When the borehole or well pipe is backfilled with bentonite pellets, depth to the top of the backfill must be continuously monitored to ensure that the pellets are not bridging within the borehole or well pipe.

Test pits, and other excavations having similar configurations, shall be backfilled and compacted.

No *permitted* groundwater monitoring well shall be abandoned without prior approval from the Director.

For each monitoring well to be abandoned, the following information must be reviewed by a Professional Geologist and provided to the Director:

- the identification of the subject well
- a description of the procedure by which the well was abandoned
- the date when the well was considered to be taken out of service
- the date when the well was abandoned

Within ***44 days*** of abandonment, a well abandonment report shall be provided to DEQ. The well abandonment report shall document the procedures and methods utilized. The well abandonment report shall be certified by a groundwater scientist, verifying that well abandonment met applicable requirements.

CLIENT: GREIF PACKAGING LLC
FACILITY: INDUSTRIAL WASTE FACILITY
LOCATION: AMHERST, VIRGINIA
PROJECT: GROUNDWATER MONITORING PROGRAM

WELL CONSTRUCTION DATA

well designation	type of well	date completed	drilling contractor	drilling method	northing	easting	diameter borehole	total depth borehole	depth to top sand	depth to top bentonite	measured well depth	stickup	corrected well depth	elevation ground surface	elevation concrete pad	elevation measuring point	elevation top steel casing
MW-01	2MW10	08-15-89	Trigon	HSA	5851.98	-657.16	8.00	79.40	66.70	64.70	79.10	1.67	77.43	660.70		662.37	
MWB-01	2MW10	09-05-89	Trigon	HSA			12.00	56.00	43.30	40.30	55.70		55.70			576.87	
RP-01	2MW10	08-25-89	Trigon	WB/RC			12.00	92.40		77.00	92.00	2.20	89.80	658.00		660.20	
MW-02					3654.60	-629.94						1.73		564.50		566.23	
RP-02																	
MW-03					3709.26	535.90						1.24		553.30		554.54	
RP-03																	
MW-04					4522.00	802.73						1.93		547.40		549.33	
RP-04																	
MW-05	2MW10	10-25-91	Fishburne	HSA	4373.34	-822.86	8.00	39.90	17.00	16.00	29.00	4.32	24.68	566.49		570.81	
RP-05	2MW10	10-25-91	Fishburne	HSA			8.00	58.00	45.00	43.00	56.30	3.91	52.39	552.74		556.65	
MW-06	2MW10	08-29-91	Fishburne	HSA	4101.34	-875.14	12.00	46.50	30.50	28.90	42.50	2.33	40.17	564.67		567.00	
RP-06	2MW10	09-06-91	Fishburne	HSA			8.00	60.00	46.50	43.50	58.00	6.27	51.73	562.02		568.29	
MW-07	2MW10	09-05-91	Fishburne	HSA	4131.79	-19.70	8.00	52.30	40.50	38.50	51.50	2.16	49.34	610.47		612.63	
RP-07	2MW10	09-06-91	Fishburne	HSA			8.00	65.00	52.00	49.00	63.70	2.84	60.86	610.87		613.71	
MW-08	2MW10	11/1/2011	Davidson	Air Rotary	4068.54	-381.81	8.00	85.00	64.00	16.00	79.89	3.00	76.89	611.25		614.25	
B-12	2MW10	05-19-83	Law	HSA	5871.04	1163.08	8.00	20.00	8.00	6.00	23.23	3.20	20.03		572.23	576.06	576.23

Fishburne - Fishburne Drilling, Inc.
Davidson - Davidson Drilling, Inc.
HSA - Hollow Stem Auger
WB/RC - Wash Boring/Rock Core
Well coordinates derived from VA Fibre grid system
Shaded cells indicate no data available

APPENDIX 4

BORING LOGS: MONITORING NETWORK

BORING LOG

BORING NO: MW-1 | ELEVATION — TOP OF BORING: 660.4 ft. | DATE OF BORING: 8/10-15/89

PROJECT: HULCHER & ASSOCIATES, VIRGINIA FIBRE LANDFILL JOB NO: 0167-001

LOCATION: AMHERST, VA | OBSERVER: KEITH STIGALL

TYPE OF BORING: 4¼" I.D. HOLLOW STEM AUGER

DRILLING CONTRACTOR: TRIGON

Stratum description (0–45 ft): ELASTIC SILT (MH)

SAMPLE DEPTH	SAMPLE BLOWS* CORE RECOVERY**	SAMPLE DESCRIPTION
1.0-2.5'	5+4+10/13"	Red ELASTIC SILT, trace fine sand, some organics, trace finely disseminated mica, dry.
3.5-5.0'	6+9+13/13"	Same as Sample No. 1, trace organics, dry.
6.0-7.5'	6+6+8/5"	Same as Sample No. 1, some organics, dry.
8.5-10.0'	5+6+8/14"	Red and yellow mottled ELASTIC SILT, trace fine sand, some organics, some finely disseminated mica, dry.
13.5-15.0'	5+8+9/12"	Same as Sample No. 4, slightly moist.
18.5-20.0'	3+6+9/11"	Same as Sample No. 5.
23.5-25.0'	3+4+6/12"	Orange and yellow mottled, light brown ELASTIC SILT, some organics, some finely disseminated mica, slightly moist.
28.5-30.0'	3+3+5/18"	Same as Sample No. 7, moist.
33.5-35.0'	4+5+6/18"	Yellow and gray mottled, light brown ELASTIC SILT, some finely disseminated mica, trace organics.
38.5-40.0	3+5+9/18"	Same as Sample No. 9, moist.
43.5-45.0	5+7+15/12"	Same as Sample No. 10, moist.

GROUND WATER DATA:

WATER LEVEL IS 621.99 FT. BELOW GROUND SURFACE 372 HRS. AFTER COMPLETION.

Groundwater encountered @ 56.0 ft.

HATCHER-SAYRE, INC.

*NO. OF BLOWS 140 LB. HAMMER 30 IN. FALL REQUIRED TO DRIVE 2 IN. O.D., 1.375 IN I.D. SAMPLER 6 INCHES.

BORING LOG

BORING NO. MW-1 | ELEVATION — TOP OF BORING: 660.4 ft. | DATE OF BORING: 8/10-15/89

PROJECT: HULCHER & ASSOCIATES, VIRGINIA FIBRE LANDFILL JOB NO: 0167-001

LOCATION: AMHERST, VA | OBSERVER: KEITH STIGALL

TYPE OF BORING: 4¼" I.D. HOLLOW STEM AUGER

DRILLING CONTRACTOR: TRIGON

DEPTH	STRATUM DESCRIPTION	SAMPLE DEPTH	SAMPLE BLOWS* CORE RECOVERY**	SAMPLE DESCRIPTION
0	ELASTIC SILT (MH)			Same as Sample No. 11, moist.
.5		48.5-50.0	16+29+36/16"	Gray to light brown, DISINTEGRATED ROCK, moist.
	SILT (ML)	53.5-55.0	33+42+51/12"	Same as Sample No. 12.
.5		58.5-59.0	53/6"/5"	Same as Sample No. 13.
60		63.5-63.8	50/4"/2"	Same as Sample No. 14, gray green.
65		68.5-69.75'	36+54+50/3"/12"	Same as Sample No. 15.
70		73.5-73.8'	50/4"/3"	Same as Sample No. 16
75		78.5-78.6'	50/1"/1½"	Same as Sample No. 17
79.4 / 80		79.4'		Auger Refusal @ 79.4'
85				
90				

GROUND WATER DATA:

WATER LEVEL IS 621.99 FT. BELOW GROUND SURFACE 372 HRS. AFTER COMPLETION.

Groundwater encountered @ 56.0 ft.

HATCHER-SAYRE, INC.

*NO. OF BLOWS 140-LB. HAMMER, 30-IN. FALL REQUIRED TO DRIVE 2 IN. O.D., 1.375 IN I.D. SAMPLER 6 INCHES.

WELL CONSTRUCTI N DETAILS

HATCHER-SAYRE, INC.

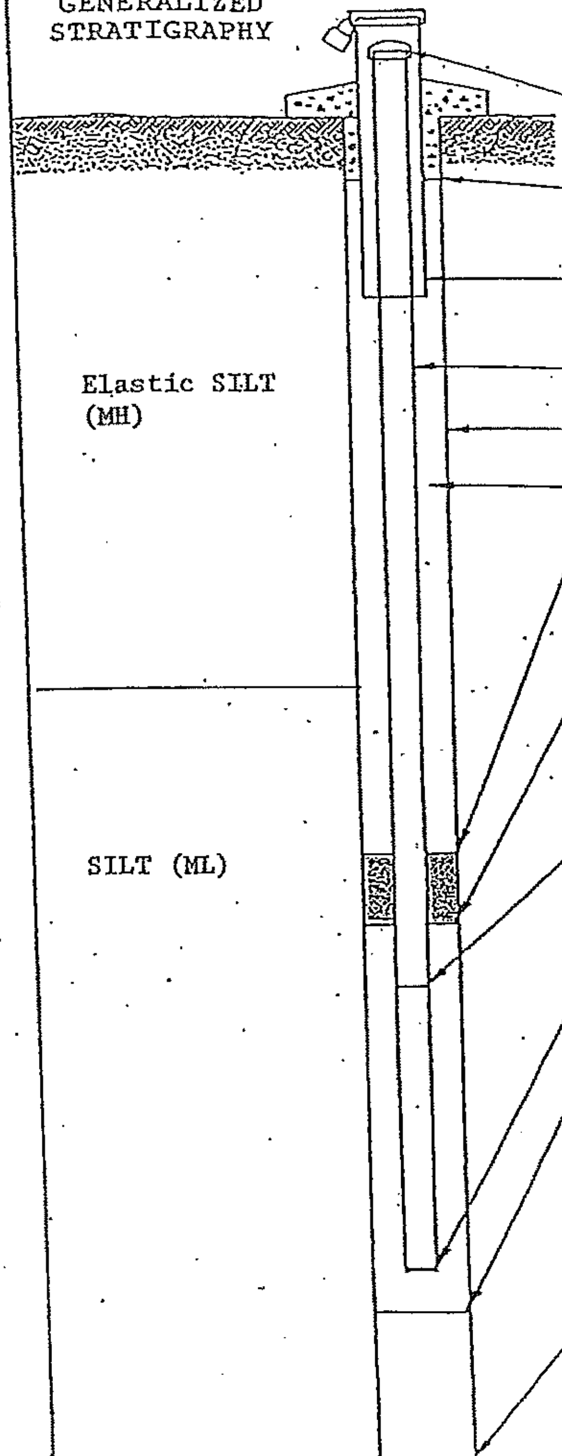
PROJECT HULCHER & ASSOCIATES, VA FIBRE — WELL NO. MW-1

SITE AMHERST, VA — JOB NO. 0167-001

DATE COMPLETED 8/10-15/89 — SUPERVISED BY K. STIGALL

DRILLER TRIGON — DRILLING/SAMPLING METHOD 4¼" I.D. HOLLOW STEM AUGER

GENERALIZED STRATIGRAPHY



WELL CONSTRUCTION DETAILS

Elevation, top of casing	662.37
Elevation, ground surface	660.7
Depth of concrete seal below ground surface	2.0
Materials and dimensions of procover	5' x 4" Steel
ID and type of riser pipe	2" I.D. Schedule 40 PVC
Diameter of borehole	8 inches
Grout composition	Bentonite/Cement
Feet below ground to top of seal	64.7
Type of seal	Bentonite
Feet below ground to top of filter pack	66.7
Type of filter pack	Filter Sand
Feet below ground to top of screen	68.7
Screen specifications	0.010 Slot Schedule 40
Feet below ground to bottom of screen	78.7
Feet below ground to bottom of filter pack	79.1
Feet below ground to top of plugged blank section	NA
Type of plug material	NA
Total depth (ft.) below ground of borehole	79.4

ADDITIONAL SPECIFICATIONS:

BORING LOG

BORING NO.: MW-5 (B5I) ELEVATION — TOP OF BORING: 566.49 DATE OF BORING: 10/17/91

PROJECT: Virginia Fibre Corp. Job No. 0300-004 AA

LOCATION: Amherst, Virginia

TYPE OF BORING: 3¼" I.D. Hollow-Stem Auger OBSERVER: JKS

DRILLING CONTRACTOR: Fishburne Drilling, Inc., Chesapeake, Virginia

DEPTH	STRATUM DESCRIPTION	SAMPLE DEPTH	SAMPLE BLOWS* CORE RECOVERY**	SAMPLE DESCRIPTION
0–39.9	SILT (ML)	4.0 – 6.0	15-13-15-19	Red & gray SILT, trace fine sand, so mica, moist
		6.0 – 8.0	11-24-43-33	Brown SILT, trace fine sand, some mi moist
		8.0 – 10.0	9-18-27-49	Same as above
		14.0 – 14.9	23-50/4"	Same as above
		16.0 – 17.3	25-35-50/3"	Same as above
		18.0 – 20.0	15-32-37-54	Brown SILT, trace fine sand, some mica, some quartz fragments, moist
		20.0 – 22.0	21-23-30-36	No sample retained
		24.0 – 25.8	26-38-48-50/	Brown SILT, trace fine sand, some mi trace rock fragments, moist
		26.0 – 26.9	29-50/4"	Same as above, wet
		28.0 – 28.9	49-50/5"	Same as above
		30.0 – 30.9	29-50/4"	Same as above
		34.0 – 34.3	50/3.5"	Brown SILT, trace fine sand, some mica, trace rock fragments, wet
		36.0 – 37.4	16-23-50/5"	Brown SILT, trace fine sand, some mica, wet
		38.0 – 38.3	50/4"	Brown SILT, some mica, some rock fragments, saturated
39.9	Boring terminated @ 39.9'	39.9		

GROUND WATER DATA:

WATER LEVEL IS ______ FT. BELOW GROUND SURFACE ______ HRS. AFTER COMPLETION.

Groundwater encountered @ 38.0'

HATCHER-SAYRE, INC.

* NO. OF BLOWS 140-LB. HAMMER, 30-IN. FALL, REQUIRED TO DRIVE 2 IN. O.D., 1.375 IN I.D. SAMPLER 6 INCHES.

BORING LOG

BORING NO.: MW-5(B51)	ELEVATION — TOP OF BORING: 566.49
DATE OF BORING: 10/17/91	Job No. 0300-004 AA
PROJECT: Virginia Fibre Corp.	
LOCATION: Amherst, Virginia	
TYPE OF BORING: 3¼" I.D. Hollow-Stem Auger	OBSERVER: JKS
DRILLING CONTRACTOR: Fishburne Drilling, Inc., Chesapeake, Virginia	

DEPTH	STRATUM DESCRIPTION	SAMPLE DEPTH	SAMPLE BLOWS* CORE RECOVERY**	SAMPLE DESCRIPTION
0–39.9	SILT (ML)	4.0–6.0	15-13-15-19	Red & gray SILT, trace fine sand, some mica, moist
		6.0–8.0	11-24-43-33	Brown SILT, trace fine sand, some mica, moist
		8.0–10.0	9-18-27-49	Same as above
		14.0–14.9	23-50/4"	Same as above
		16.0–17.3	25-35-50/3"	Same as above
		18.0–20.0	15-32-37-54	Brown SILT, trace fine sand, some mica, some quartz fragments, moist
		20.0–22.0	21-23-30-36	No sample retained
		24.0–25.8	26-38-48-50/	Brown SILT, trace fine sand, some mica, trace rock fragments, moist
		26.0–26.9	29-50/4"	Same as above, wet
		28.0–28.9	49-50/5"	Same as above
		30.0–30.9	29-50/4"	Same as above
		34.0–34.3	50/3.5"	Brown SILT, trace fine sand, some mica, trace rock fragments, wet
		36.0–37.4	16-23-50/5"	Brown SILT, trace fine sand, some mica, wet
		38.0–38.3	50/4"	Brown SILT, some mica, some rock fragments, saturated
		39.9		
39.9	Boring terminated @ 39.9'			

GROUND WATER DATA:

WATER LEVEL IS ______ FT. BELOW GROUND SURFACE ______ HRS. AFTER COMPLETION.

No groundwater encountered

HATCHER-SAYRE, INC.

* ... SAMPLER 6 INCHES.

MONITORING WELL CONSTRUCTION LOG

MONITORING WELL : MW-5 JOB NO. 0300-004AA DATE : 10/22&25/91

PROJECT : Virginia Fibre Corporation

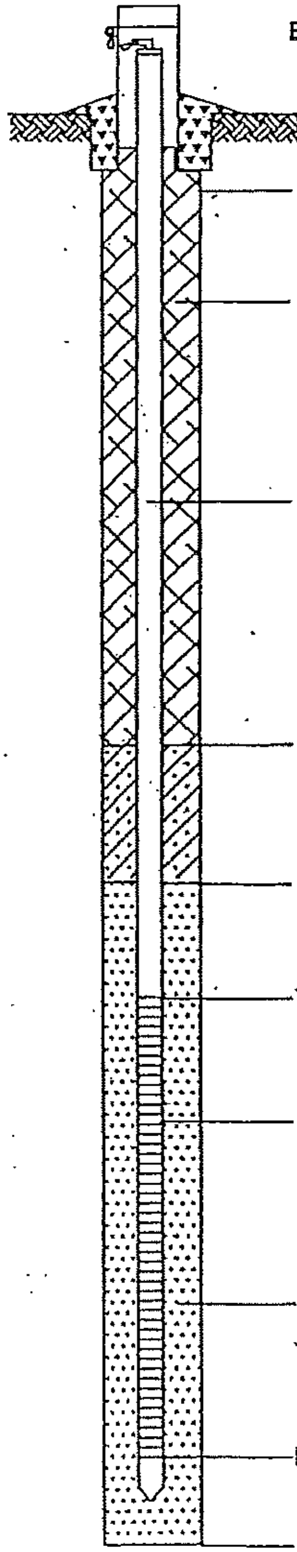
SITE LOCATION : Amherst County, VA GEOLOGIST : JKS

DRILLING CONTRACTOR : Fishburne Drilling Co., Inc.

HATCHER-SAYRE, INC.

GENERALIZED STRATIGRAPHY

SILT (ML)



ELEVATIONS : GROUND SURFACE : 566.49
TOP OF CASING : 570.81
NOTCH : 570.47

DIAMETER OF BORING 0.66 FEET

GROUT TYPE : % BENTONITE 10
% CEMENT 90

CASING TYPE : MATERIAL PVC
SCHEDULE 40
INNER DIAMETER 0.16 FEET

TOP OF BENTONITE SEAL : DEPTH 16 FEET
ELEV. 550.49

TOP OF SAND PACK : DEPTH 17 FEET
ELEV. 549.49

TOP OF SCREEN : DEPTH 19 FEET
ELEV. 547.49

SCREEN TYPE : MATERIAL PVC
SCHEDULE 40
INNER DIAMETER 0.16 FEET
SLOT SIZE 0.010

SAND PACK TYPE : GRAIN SIZE 1.431
ORIGIN Foster-Dixiana
Columbia, SC

BOTTOM OF SCREEN : DEPTH 29 FEET
ELEV. 537.49

BOTTOM OF BORING : DEPTH 39.9 FEET
ELEV. 526.59

BORING LOG

BORING NO.: MW-6 | ELEVATION — TOP OF BORING: 564.67 | DATE OF BORING: 8/29/91

PROJECT: Virginia Fibre Corp. | Job No. 0300-004 AA

LOCATION: Amherst, Virginia

TYPE OF BORING: 6¼" I.D. Hollow-Stem Auger | OBSERVER: JKS

DRILLING CONTRACTOR: Fishburne Drilling, Inc., Chesapeake, Virginia

DEPTH	STRATUM DESCRIPTION	SAMPLE DEPTH	SAMPLE BLOWS* CORE RECOVERY**	SAMPLE DESCRIPTION
0	SILT (ML)	0.0 – 2.0	15-16-11-13	Red SILT, trace clay, trace fine sand, trace mica, trace root fragments, moist
		2.0 – 4.0	14-22-24-26	Reddish brown SILT, some mica, trace fine sand, moist
5		4.0 – 6.0	8-8-13-20	Same as above
		6.0 – 8.0	13-24-50/4"	Same as above
		8.0 – 10.0	8-14-16-18	Same as above
10		10.0 – 12.0	7-12-17-21	Same as above
		12.0 – 14.0	24-31-33-45	Brown SILT, trace fine sand, some mica, wet
15		14.0 – 16.0	25-33-33-37	Same as above
		16.0 – 18.0	35-36-35-42	Same as above
		18.0 – 20.0	9-16-19-24	Same as above
20		20.0 – 22.0	10-30-43-28	Same as above
		22.0 – 23.9	28-27-46-50/4"	Brown SILT, trace fine to coarse sand, some mica, trace rock fragments, wet
25		24.0 – 25.4	16-42-50/5"	Brown SILT, trace fine sand, some mica, wet
		26.0 – 27.8	29-39-47-50/4"	Same as above
		28.0 – 29.5	22-45-51/6"	Brown SILT, trace fine to coarse sand, some mica, wet
30		30.0 – 30.9	21-50/5"	Same as above
		32.0 – 34.0	16-27-26-28	Same as above
35	Quartz Fragments	34.0 – 36.0	30-24-36-45	Yellowish brown quartz fragments, saturated
	SILT (ML)	36.0 – 37.3	44-47-50/4"	Brown SILT, some fine sand, some mica, wet
		38.0 – 38.7	54-50/2"	Same as above
40		40.0 – 40.3	50/4"	Brown SILT, some fine to coarse sand, some mica, trace rock fragments, wet
		42.0 – 42.3	50/4"	Same as above
45		44.0 – 44.3	50/4"	Same as above

GROUND WATER DATA:

WATER LEVEL IS ________ FT. BELOW GROUND SURFACE ________ HRS. AFTER COMPLETION.

No groundwater encountered

HATCHER-SAYRE, INC.

* NO. OF BLOWS 140-LB. HAMMER, 30-IN. FALL, REQUIRED TO DRIVE 2 IN. O.D., 1.375 IN I.D. SAMPLER 6 INCHES.

** CORE RECOVERY AS PERCENT OF LENGTH OF DRILL RUN.

BORING NO.: MW-6 | PROJECT: Virg[illegible]a Fibre Corp. | Job No. 300-004 AA

DEPTH	STRATUM DESCRIPTION	SAMPLE DEPTH	SAMPLE BLOWS* CORE RECOVERY**	SAMPLE DESCRIPTION
45	SILT	46.0	50/4"	Same as above
	Sampler Refusal @ 46.0'	46.5	35/0"	No sample retained
	Auger Refusal @ 46.5'			
50				
55				
60				
65				
70				
75				
80				
85				
90				
95				
100				

* NO. OF BLOWS 140-LB. HAMMER, 30-IN. FALL, REQUIRED TO DRIVE 2 IN. O.D., 1.375 IN I.D. SAMPLER 6 INCHES.

** CORE RECOVERY AS PERCENT OF LENGTH OF DRILL RUN.

HATCHER-SAYRE, INC.

MONITORING WELL CONSTRUCTION LOG

MONITORING WELL: MW-6 JOB NO.: 0300-004AA DATE: 8/29/91

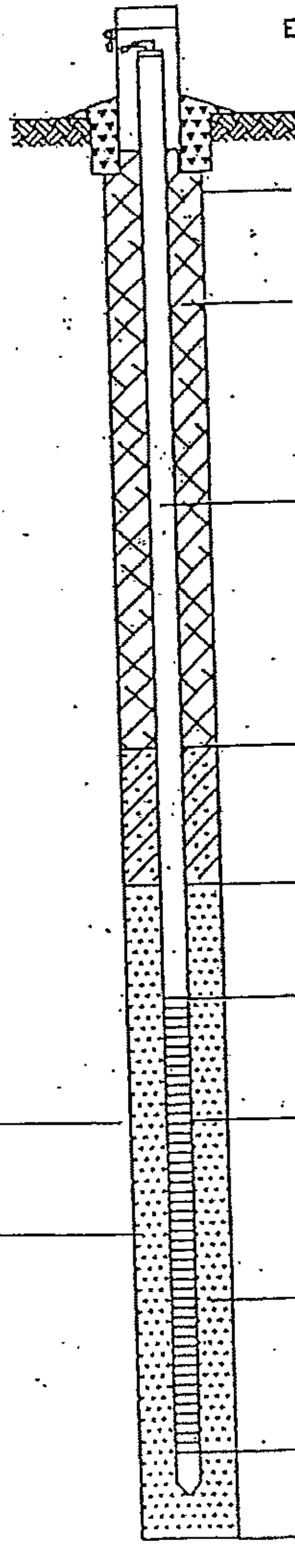
PROJECT: Virginia Fibre Corp.-New Landfill

SITE LOCATION: Amherst Co., VA GEOLOGIST: JKS

DRILLING CONTRACTOR: Fishburne Drilling Co., Inc.

HATCHER-SAYRE, INC.

GENERALIZED STRATIGRAPHY



ELEVATIONS: GROUND SURFACE: 564.67
TOP OF CASING: 567.00
NOTCH: 566.49

DIAMETER OF BORING 1.0 FEET

GROUT TYPE: % BENTONITE 10
% CEMENT 90

CASING TYPE: MATERIAL PVC
SCHEDULE 40
INNER DIAMETER 0.167 FEET

SILT

TOP OF BENTONITE SEAL: DEPTH 28.9 FEET
ELEV. 535.77

TOP OF SAND PACK: DEPTH 30.5 FEET
ELEV. 534.17

TOP OF SCREEN: DEPTH 32.5 FEET
ELEV. 532.17

SCREEN TYPE: MATERIAL PVC
SCHEDULE 40
INNER DIAMETER 0.167 FEET
SLOT SIZE 0.010

Quartz Fragments

SAND PACK TYPE: GRAIN SIZE 1.431
ORIGIN Foster-Dixiana Columbia, SC

SILT

BOTTOM OF SCREEN: DEPTH 42.5 FEET
ELEV. 522.17

BOTTOM OF BORING: DEPTH 43.0 FE.
ELEV. 521.67

BORING LOG

BORING NO: MW-7	ELEVATION — TOP OF BORING: 610.47	DATE OF BORING: 9/5/91 & 9/6/91	
PROJECT: Virginia Fibre Corp.		Job No. 0300-004 AA	
LOCATION: Amherst, Virginia			
TYPE OF BORING: 6¼" I.D. Hollow-Stem Auger		OBSERVER: JKS	
DRILLING CONTRACTOR: Fishburne Drilling, Inc., Chesapeake, Virginia			

DEPTH	STRATUM DESCRIPTION	SAMPLE DEPTH	SAMPLE BLOWS* CORE RECOVERY**	SAMPLE DESCRIPTION
0	SILT (ML)	0.0–2.0	6-6-6-8	Red SILT, trace fine sand, some mica, trace root fragments, moist
		2.0–4.0	12-10-12-11	Same as above
5		4.0–6.0	8-8-12-14	Same as above
		6.0–8.0	16-18-23-29	Brown SILT, trace fine sand, some mica moist
		8.0–10.0	4-8-16-31	Same as above
10		10.0–12.0	12-24-32-30	Same as above
		12.0–14.0	29-34-44-44	Same as above
15		14.0–16.0	8-15-23-27	Same as above
		16.0–18.0	24-36-36-48	Same as above
		18.0–20.0	10-20-52-37	Same as above
20		20.0–22.0	6-18-25-34	Same as above
		22.0–24.0	34-46-42-41	Brown SILT, trace fine sand, some mi[illegible] trace rock fragments, moist
25		24.0–25.4	6-36-60/5"	Same as above
		26.0–26.7	46-55/2.5"	Same as above
		28.0–28.6	40-50/1"	Same as above
30		30.0–30.1	50/1"	No sample retained
		32.0–33.4	13-32-50/5"	Brown SILT, trace fine sand, some mic trace rock fragments, moist
35		34.0–34.8	52-50/4"	Same as above
		36.0–36.2	50/2.5"	No sample retained
	Quartz Fragments	38.0–38.4	50/5"	Yellowish brown quartz fragments, som mica, moist
40	SILT (ML)	40.0–40.3	50/4"	No sample retained
		42.0–42.8	29-50/4"	Brown SILT, some rock fragments, some mica, moist
45		44.0–44.1	50/1"	No sample retained

GROUND WATER DATA:

WATER LEVEL IS ______ FT. BELOW GROUND SURFACE ______ HRS. AFTER COMPLETION.

No groundwater encountered

HATCHER-SAYRE, INC.

* NO. OF BLOWS 140-LB. HAMMER, 30-IN. FALL, REQUIRED TO DRIVE 2 IN. O.D., 1.375 IN I.D. SAMPLER 6 INCHES.

BORING LOG (CONTINUATION)

BORING NO.: MW-7 PROJECT: Virginia Fibre Corp. Job No. 0300-004 AA

DEPTH	STRATUM DESCRIPTION	SAMPLE DEPTH	SAMPLE BLOWS* CORE RECOVERY**	SAMPLE DESCRIPTION
45	SILT (ML)	46.0 46.2	50/1"	No sample retained
		48.0 48.3	50/2.5"	No sample retained
50		50.0 50.3	50/4"	No sample retained
		52.0 52.3	50/4"	No sample retained
	Boring terminated @ 52.3'			
55				
60				
65				
70				
75				
80				
85				
90				
95				
100				

* NO. OF BLOWS 140-LB. HAMMER, 30-IN. FALL, REQUIRED TO DRIVE 2 IN. O.D., 1.375 IN I.D. SAMPLER 6 INCHES.

** CORE RECOVERY AS PERCENT OF LENGTH OF DRILL RUN.

MONITORING WELL CONSTRUCTION LOG

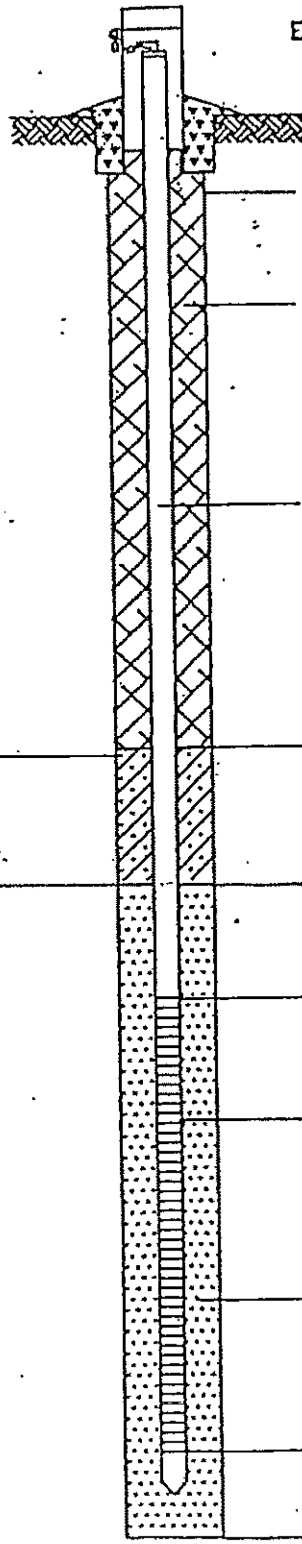
MONITORING WELL : MW-7 JOB NO. 0300-004AA DATE : 9/5/91

PROJECT : Virginia Fibre Corp. - New Landfill

SITE LOCATION : Amherst Co., VA GEOLOGIST : JKS

DRILLING CONTRACTOR : Fishburne Drilling Co., Inc.

HATCHER-SAYRE, INC.



GENERALIZED STRATIGRAPHY

SILT

Quartz Fragments

SILT

ELEVATIONS : GROUND SURFACE : 610.47
TOP OF CASING : 612.63
NOTCH : 611.35

DIAMETER OF BORING 0.67 FEET

GROUT TYPE : % BENTONITE 10
% CEMENT 90

CASING TYPE : MATERIAL PVC
SCHEDULE 40
INNER DIAMETER 0.167 FEET

TOP OF BENTONITE SEAL : DEPTH 38.5 FEET
ELEV. 571.97

TOP OF SAND PACK : DEPTH 40.5 FEET
ELEV. 569.97

TOP OF SCREEN : DEPTH 41.5 FEET
ELEV. 568.97

SCREEN TYPE : MATERIAL PV
SCHEDULE 40
INNER DIAMETER 0.167 FEET
SLOT SIZE 0.010

SAND PACK TYPE : GRAIN SIZE 1.431
ORIGIN Foster-Dixiana
Columbia, SC

BOTTOM OF SCREEN : DEPTH 51.5 FEET
ELEV. 558.97

BOTTOM OF BORING : DEPTH 52.0 FEET
ELEV. 558.47

DRAPER ADEN ASSOCIATES
Engineers • Geologists • Hydrologists

LOG OF: **MW-08**
(1 of 2)

Project Number: 22299

Client:	Greif Packaging LLC	Drilling Company:	Davidson Drilling, Inc.
Project:	Industrial Landfill	Driller:	M. Helms
Location:	Amherst County, Virginia	Boring Method:	8" Air Rotary
North: 4,068.54	East: -381.81	Logged by:	JCN
Total Depth 85.0' Elev GS: 611.25	Reference: Ground Surface	Completion Date:	November 1, 2011

Samp ID	Blow Counts	N Value	Depth Scale	DESCRIPTION (USC)	GEOL	Stratum Elev	WELL LOG	H_2O	REMARKS
			0	Red,SILT, trace fine sand; moist. (ML)					Stickup = 3.00 ft. 4" x 4" Steel Protective Casing. 3' x 3' x 3.5" Concrete Pad.
			5						Grout / Bentonite Slurry.
			10	Yellow-brown, SILT; moist. (ML)					
			15	Yellow-brown, SILT, trace fine sand; moist. (ML)				595.25	Top of Bentonite.
			20	Red, SILT; moist. (ML)					2" I.D., Sch. 40, PVC Riser.
			25						
			30	Red, SILT, trace fine sand and quartz fragments; moist. (ML)					
			35						
			40	Red, SILT; moist. (ML)					
			45						

WELL LOG 3 GREIF ILF.GPJ DRAPER ADEN.GDT 11/28/11

Project Number: 22299

Client:	**Greif Packaging LLC**	Drilling Company:	**Davidson Drilling, Inc.**
Project:	**Industrial Landfill**	Driller:	**M. Helms**
Location:	**Amherst County, Virginia**	Boring Method:	**8" Air Rotary**
North: **4,068.54**	East: **-381.81**	Logged by:	**JCN**
Total Depth **85.0'** Elev GS: **611.25**	Reference: **Ground Surface**	Completion Date:	**November 1, 2011**

Samp ID	Blow Counts	N Value	Depth Scale	DESCRIPTION (USC)	GEOL	Stratum Elev	WELL LOG	H_2O	REMARKS
			50	Red, SILT, trace fine sand; moist. (ML)					
									Bentonite.
			55	Red, SILT, trace quartz fragments; moist. (ML)					2" I.D., Sch. 40, PVC Riser.
			60	Red, SILT; moist. (ML)					
								547.25	11/10/11: DTW = 63.20 ft. Top of Sand.
			65					544.75	
									2" I.D., Sch. 40, PVC Well Screen; Factory Slotted (0.01").
			70						
				Becoming wet.					DDW = 72 ft.
			75	Red, SILT, trace quartz fragments (saprolite); wet.					
								534.75	
								534.36	
			80	Greenstone.		531.25			
								529.25	
									Cuttings.
			85	Boring terminated at 85 feet. Groundwater encountered at 72 feet. Monitoring well MW-08 constructed.		526.25		526.25	K = 2.43E-3 cm/sec (estimated).
									This well appears to have been constructed in accordance with applicable plans and specifications.
			90						
									- Leonard Ford (CPG 796)
			95						

EXPLANATION OF MONITORING WELL NUMBERING CHANGES

The reports and information contained in this Appendix refer to Hatcher - Sayre, Inc. monitoring wells MW-5, MW-6, MW-7 and MW-8, which have been redesignated MW B-1, MW B-2, MW B-3 and MW B-4 since their installation.

The "MW B" series designation is used in the closure plan and associated plans prepared by Hulcher & Associates, Inc. The wells correlate as follows:

MW B-1	=	MW-5
MW B-2	=	MW-8
MW B-3	=	MW-6
MW B-4	=	MW-7

SHIELD ENVIRONMENTAL ASSOCIATES, INC.

MONITORING WELL CONSTRUCTION SUMMARY

Facility Name/Location:	Facility ID No.:	Date:	Constructed By (Name and Firm):	Project No.:
Bark Landfill *Virginia Fibre Corporation* *Amherst County, Virginia*			*Trigon (MW B-1, MW B-3)* *Fishburne Drilling Co. (MW B-2, MW B-4) under inspection of Hatcher-Sayre, Inc.*	5940070

Well Name	Well ID No.	Well Location	Install Date	Well Casing		Elevations				Reference		Screen		Well Depth (Ft.)	Remarks
				Dia.	Type	Top of Well Casing (Ft.)	Top of PVC (Ft.)	Ground Surface (Ft.)	Screen Top (Ft.)	MSL (✓)	Site Datum (✓)	Length (Ft.)	Material		
MW B-1 (HSI/MW-5)		N = 3254.68' E = 2717.57'	9/5/89	2"	PVC	577.42	576.87	574.58	528.58	✓		10.0	0.010 Slot	56.0	Auger Refusal at 56.0'.
MW B-2 (HSI/MW-8)		N = 3277.30' E = 3625.49'	8/28/91	2"	PVC	498.07	497.64	495.67	471.67	✓		10.0	0.010 Slot	34.0	Auger Refusal at 34.0'; Sampler Refusal at 35.0'.
MW B-3 (HSI/MW-6)		N = 3009.07' E = 3637.71'	9/6/89	2"	PVC	478.24	477.27	475.82	468.82	✓		4.5	0.010 Slot	11.5	Sampler and Auger Refusal at 11.5'.
MW B-4 (HSI/MW-7)		N = 2160.33' E = 3762.41'	8/28/91	2"	PVC	456.91	456.69	454.90	440.90	✓		10.0	0.010 Slot	24.0	Auger Refusal at 24.0'; Sampler Refusal at 24.8'.

ADDITIONAL COMMENTS:

BORING LOG

BORING NO.: MW-5	ELEVATION — TOP OF BORING:	DATE OF BORING: 9/5/89
PROJECT: HULCHER & ASSOCIATES, VIRGINIA FIBRE LANDFILL		JOB NO. 0167-003
LOCATION: AMHERST COUNTY, VA		
TYPE OF BORING: 4¼ I.D. HOLLOW STEM AUGER		OBSERVER: K. STIGALL
DRILLING CONTRACTOR: TRIGON		

DEPTH	STRATUM DESCRIPTION	SAMPLE DEPTH	SAMPLE BLOWS* CORE RECOVERY**	SAMPLE DESCRIPTION
0–1.0	FILL	1.0-2.5'	6+9+18/15"	0.0-1.0' fine to coarse gravel cuttings (driveway). Red and light brown mottled ELASTIC SILT, some finely disseminated mica, trace organics, slightly moist.
1.0–28.5	ELASTIC SILT (MH)	3.5-5.0'	7+9+16/18"	
		6.0-7.5'	14+18+22/17"	Red and light brown mottled ELASTIC SILT, trace organics, trace fine sand, trace fine gravel, some finely disseminated mica, slightly moist
		8.5-10.0'	18+31+51/15"	Same as Sample No. 2, no gravel, dry
				Same as Sample No. 3, dry
		13.5-15.0'	23+45+39/13"	Same as Sample No. 4, dry
		18.5-20.0'	26+40+50/4"/9.5"	Sampler started bouncing Same as Sample No. 5, dry
		23.5-25.0'	31+50/4"/7.5"	Sampler bouncing Same as Sample No. 6, tough, dry
28.5–45	SILT (ML)	28.5-30.0'	50/3"/1"	Sampler bouncing Gray, green SILT, some finely disseminated mica, dry
		33.5-35.0'	50/3"/1.5"	Sampler bouncing. Same as Sample No. 8, dry
		38.5-40.0'	50/2"/0"	Sampler bouncing NO RECOVERY.
		43.5-45.0'	44+50/3"/6"	Gray green fine SANDY SILT, some finely disseminated mica, dry

GROUND WATER DATA:

WATER LEVEL IS 43.36 FT. BELOW GROUND SURFACE 24 HRS. AFTER COMPLETION.

HATCHER-SAYRE, INC.

* NO. OF BLOWS 140-LB. HAMMER, 30-IN. FALL, REQUIRED TO DRIVE 2 IN. O.D., 1.375 IN I.D. SAMPLER 6 INCHES.
** CORE RECOVERY AS PERCENT OF LENGTH OF DRILL RUN.
SEE NOTES TO BORING LOG WHICH ARE A PART OF THIS LOG.

BORING LOG

BORING NO.: MW-5	ELEVATION — TOP OF BORING:	DATE OF BORING: 9/5/89
PROJECT: HULCHER & ASSOCIATES, VIRGINIA FIBRE LANDFILL		JOB NO. 0167-003
LOCATION: AMHERST COUNTY, VA		
TYPE OF BORING: 4¼ I.D. HOLLOW STEM AUGER		OBSERVER: K. STIGALL
DRILLING CONTRACTOR: TRIGON		

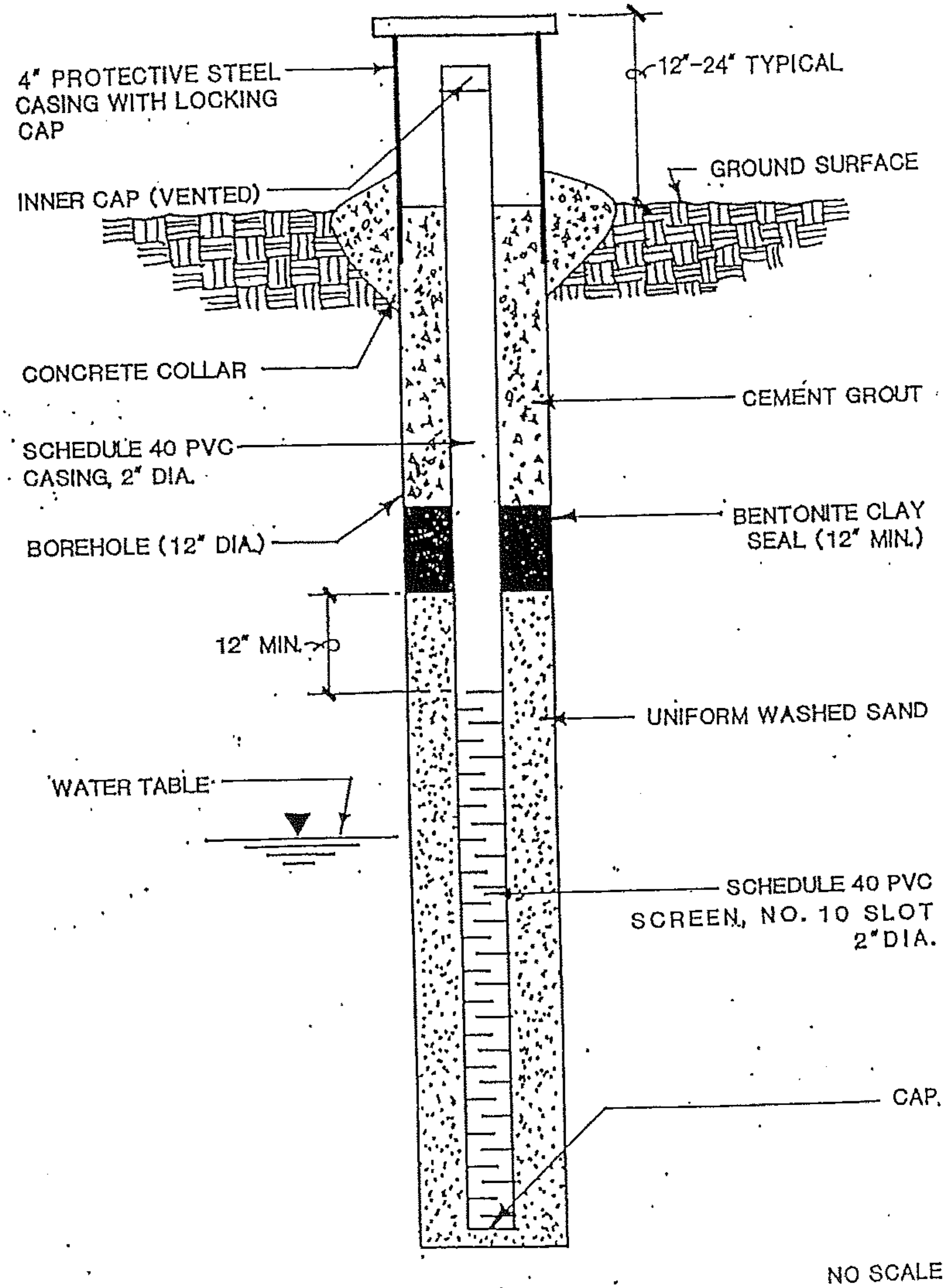
DEPTH	STRATUM DESCRIPTION	SAMPLE DEPTH	SAMPLE BLOWS* CORE RECOVERY**	SAMPLE DESCRIPTION
45				
	SILT (ML)	48.5-50.0'	50/4"/2.5"	Same as Sample No. 11, moist cuttings come up moist @ 52'
50				
		53.5-55.0'	50/ 1"/0"	Sampler Refusal
55				
56		56.0'		Auger Refusal
				Boring terminated at 56.0 ft.
60				

GROUND WATER DATA:
WATER LEVEL IS 43.36 FT. BELOW GROUND SURFACE 24 HRS. AFTER COMPLETION.

HATCHER-SAYRE, INC.

* NO. OF BLOWS 140-LB. HAMMER, 30-IN. FALL, REQUIRED TO DRIVE 2 IN. O.D., 1.375 IN I.D. SAMPLER 6 INCHES.
** CORE RECOVERY AS PERCENT OF LENGTH OF DRILL RUN.
SEE NOTES TO BORING LOG WHICH ARE A PART OF THIS LOG.

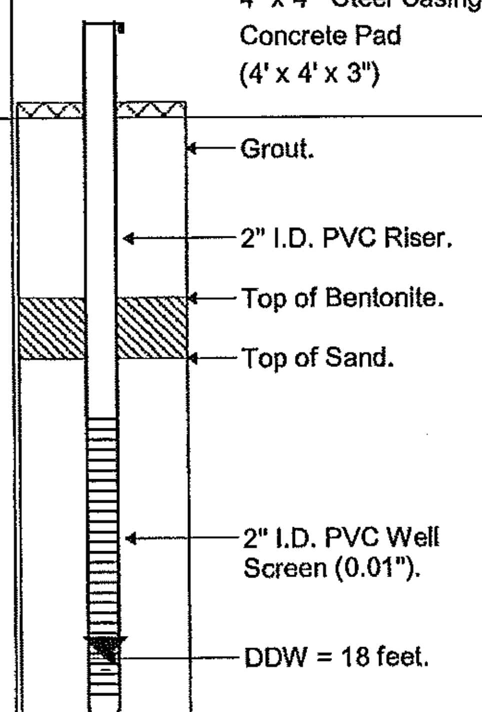
TYPICAL GROUNDWATER MONITORING WELL



Draper Aden Associates
8090 Villa Park Drive
Richmond, Virginia 23228
www.daa.com

Client: Greif Packaging	Boring No: B-12
Project: Greif Packaging Facility	Project No: 22299
Location: Riverville, Virginia	Drilling Contractor: Law Engineering
North: 37.516687	Driller: Law Engineering
East: 78.916716	Drilling Method: HSA
Total Depth: 20	Logged by: Law Engineering
Reference: Ground Surface	Completion Date: 5-19-83

Sample ID.	N-Value	Depth	Geology	DESCRIPTION (USCS)	Elevation	WELL LOG
		-5.0				
		0.0		Ground Surface		
				Very hard, gray, fine sandy SILT with trace mica. (ML)		
		5.0				
1	44					
		10.0				
		15.0				
2	50 1"			Becoming wet.		
		20.0		Auger refusal at 20 feet. Groundwater encountered at 18 feet. Monitoring well B-12 constructed.		Boring log prepared from infromation provided in geotechnical report prepared by Law Engineering Testing Compay; dated November, 1983.
		25.0				
		30.0				
		35.0				



APPENDIX 4

BORING LOGS: ADDITIONAL WELLS

BORING LOG

BORING NO.: MW-2	ELEVATION — TOP OF BORING: 566.23 ft.	DATE OF BORING: 8/2-3/89
PROJECT: HULCHER & ASSOCIATES, VIRGINIA FIBRE LANDFILL JOB NO: 0167-001		
LOCATION: AMHERST, VA		
TYPE OF BORING: 4¼" I.D. HOLLOW STEM AUGER		OBSERVER: KEITH STIGALL
DRILLING CONTRACTOR: TRIGON		

STRATUM DESCRIPTION	SAMPLE DEPTH	SAMPLE BLOWS* CORE RECOVERY**	SAMPLE DESCRIPTION
LEAN CLAY (CL)	1.0-2.5'	4+4+11/16"	Tan mottled LEAN CLAY, trace organics, trace finely disseminated mica, trace coarse sand, dry.
	3.5-5.0	7+12+13/18"	Red LEAN CLAY, trace organics, some fine to coarse sand and gravel, dry.
	6.0-7.5'	10+9+10/13"	Red LEAN CLAY, trace fine to coarse sand trace fine gravel, trace finely disseminated mica, dry.
ELASTIC SILT (MH)	8.5-10.0'	5+5+8/15"	Tan ELASTIC SILT, some fine to coarse sand and gravel, some finely disseminated mica, dry.
SILT (ML)	13.5-15.0	4+5+6/18"	Gray and tan SILT, some fine to coarse sand, some finely disseminated mica, slightly moist.
	18.5-20.0	4+5+6/18"	Same as Sample No. 5, trace organics, very fine sand.
	23.5-25.0	3+5+6/18"	Same as Sample No. 6, coarse sand to fine gravel.
	28.5-30.0	4+3+8/18"	Same as Sample No. 7, moist.
	33.5-35.0	2+2+2/18"	Same as Sample No. 8, saturated @ 34.5'
	38.5-40.0	3+4+6/18"	Same as Sample No. 9, fine sand, no gravel.
	43.5-45.0	2+2+4/18"	Same as Sample No. 10.

GROUND WATER DATA:

WATER LEVEL IS 532.58 FT. BELOW GROUND SURFACE 663 HRS. AFTER COMPLETION.

Groundwater encountered @ 34.0 ft.

HATCHER-SAYRE, INC.

* NO. OF BLOWS 140-LB. HAMMER, 30-IN. FALL, REQUIRED TO DRIVE 2 IN. O.D., 1.375 IN I.D. SAMPLER 6 INCHES.
** CORE RECOVERY AS PERCENT OF LENGTH OF DRILL RUN.
SEE NOTES TO BORING LOG WHICH ARE A PART OF THIS LOG.

BORING LOG

BORING NO.: MW-2	ELEVATION — TOP OF BORING: 566.23 ft.		DATE OF BORING: 8/2-3/89
PROJECT: HULCHER & ASSOCIATES, VIRGINIA FIBRE LANDFILL JOB NO: 0167-001			
LOCATION: AMHERST, VA			
TYPE OF BORING: 4¼" I.D. HOLLOW STEM AUGER			OBSERVER: KEITH STIGALL
DRILLING CONTRACTOR: TRIGON			

DEPTH	STRATUM DESCRIPTION	SAMPLE DEPTH	SAMPLE BLOWS* CORE RECOVERY**	SAMPLE DESCRIPTION
45				Same as Sample No. 10.
	SILT (ML)	48.5-50.0'	3+3+7/8"	Same as Sample No. 11, trace medium sand.
50				
53.8		53.5-53.6', 53.8'	50/½"/½"	DISINTEGRATED ROCK, saturated
55				Auger & Sampler Refusal @ 53.8'
60				

GROUND WATER DATA:

WATER LEVEL IS 532.58 FT BELOW GROUND SURFACE 663 HRS. AFTER COMPLETION.

Groundwater encountered @ 34.0 ft.

HATCHER-SAYRE, INC.

* NO. OF BLOWS 140-LB. HAMMER, 30-IN. FALL, REQUIRED TO DRIVE 2 IN. O.D., 1.375 IN I.D. SAMPLER 6 INCHES.

** CORE RECOVERY AS PERCENT OF LENGTH OF DRILL RUN.

SEE **NOTES TO BORING LOG** WHICH ARE A PART OF THIS LOG.

Client: Hulcher & Associates

Project: Virginia Fibre Landfill

Location: Amherst, Va

North: 36+54.596

East: -6+29.938

Total Depth: 53.8 feet

Reference: Ground surface

Boring No: MW-2

Project No:

Drilling Contractor: Trigon

Driller: Trigon

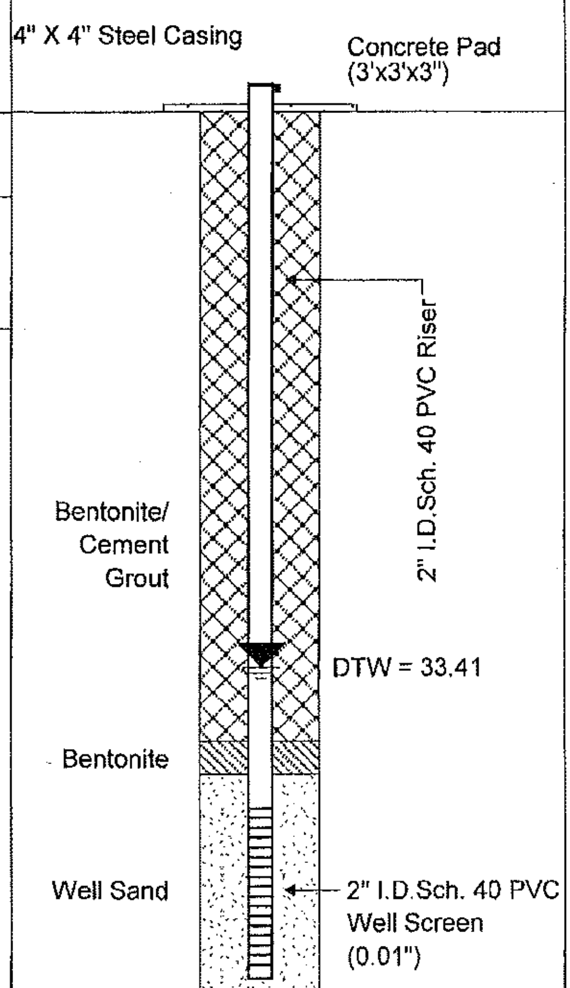
Drilling Method: 4.25" I.D. HSA

Logged by: K. Stigall

Completion Date: 8-3-89

Depth	Geology	DESCRIPTION (USCS)	Elev.
-5.0			
0.0		Ground Surface	564.50
		CLAY	559.50
5.0		Elastic SILT	
10.0			551.50
15.0		SILT	
20.0			
25.0			
30.0			
35.0			
40.0			
45.0			
50.0			510.70
55.0		Auger refusal at 53.8 feet.	
60.0			
65.0			

WELL LOG



Monitoring well AS-Built prepared from information provided by Hatcher-Sayre.

ROCK PIEZOMETER CONSTRUCTION LOG

MONITORING WELL : RP-1A JOB NO. : 0167-001 DATE : 8/24-25/89
PROJECT : Hulcher & Associates - Virginia Fibre
SITE LOCATION : Amherst Co., Virginia GEOLOGIST : J.K.Stigall
DRILLING CONTRACTOR : Trigon

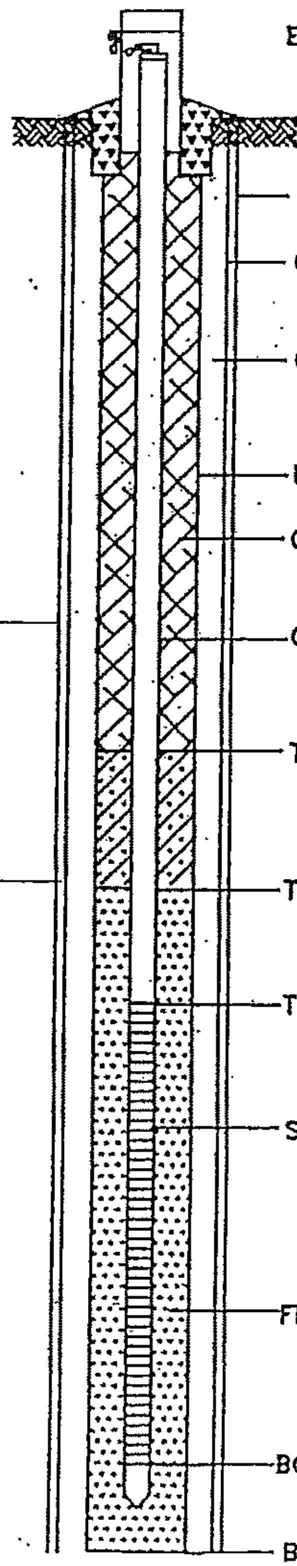
HATCHER-SAYRE, INC.

GENERALIZED STRATIGRAPHY

Elastic SILT (MH)

SILT (ML)

GREENSTONE



ELEVATIONS : GROUND SURFACE : 658.0'
TOP OF CASING : 660.20'
NOTCH : ______

DIAMETER OF BORING 1.0 FEET

GROUT TYPE : % BENTONITE 10
% CEMENT 90

CASING TYPE : MATERIAL PVC
SCHEDULE 40
INNER DIAMETER 0.33 FEET

DIAMETER OF BORING 0.67 FEET

GROUT TYPE : % BENTONITE 10
% CEMENT 90

CASING TYPE : MATERIAL PVC
SCHEDULE 40
INNER DIAMETER 0.17 FEET

TOP OF BENTONITE SEAL : DEPTH 77.0 FEET
ELEV. ______

TOP OF FILTER PACK : DEPTH NA FEET
ELEV. NA

TOP OF SCREEN : DEPTH 82.0 FEET
ELEV. ______

SCREEN TYPE : MATERIAL PVC
SCHEDULE 40
INNER DIAMETER 0.17 FEET
SLOT SIZE 0.010

FILTER PACK TYPE : None

BOTTOM OF SCREEN : DEPTH 92.0 FEET
ELEV. ______

BOTTOM OF BORING : DEPTH 92.4 FEET
ELEV. ______

BORING LOG

BORING NO.: RP-5(B5M)	ELEVATION — TOP OF BORING: 552.74
DATE OF BORING: 10/23/91	
PROJECT: Virginia Fibre Corp.	Job No. 0300-004 AA
LOCATION: Amherst, Virginia	
TYPE OF BORING: 3¼" I.D. Hollow-Stem Auger	OBSERVER: JKS
DRILLING CONTRACTOR: Fishburne Drilling, Inc., Chesapeake, Virginia	

DEPTH	STRATUM DESCRIPTION	SAMPLE DEPTH	SAMPLE BLOWS*. CORE RECOVERY**	SAMPLE DESCRIPTION
0		0.0–2.0		Red SILT, some mica, trace quartz fragments, moist
		2.0–4.0		Same as above
5		4.0–6.0	6-10-13-15	Same as above
		6.0–8.0	11-12-17-18	Same as above
		8.0–10.0	5-8-10-13	Reddish brown SILT, trace clay, some mica, trace quartz fragments, moist
10		10.0–12.0	12-17-18-27	Brown SILT, trace fine sand, some mica, moist
		12.0–14.0	5-4-6-6	Dark brown SILT, some mica, wet to saturated
15		14.0–16.0	3-3-4-4	Same as above, saturated
		16.0–18.0	1-2-2-4	Same as above
		18.0–20.0	2-1-2-1	Dark brown SILT, some fine sand, some mica, saturated
20		20.0–22.0	1-1-2-2	Same as above
	SILT (ML)	22.0–24.0	1-0-0-4	Dark greenish gray SILT, trace fine sand, some mica, saturated
25		24.0–26.0	2-2-4-5	Same as above
		26.0–28.0	3-4-4-7	Same as above
		28.0–30.0	3-3-3-4	Same as above
30		30.0–32.0	2-4-10-11	Dark greenish gray fine sandy SILT, some mica, trace rock fragments, saturated
		32.0–34.0	5-5-5-4	Dark gray fine sandy SILT, some mica, trace rock fragments, saturated
35		34.0–36.0	2-2-2-4	Dark greenish gray SILT, trace fine sand, some mica, saturated
		36.0–38.0	12-35/2"	Dark greenish gray SILT, some fine san[d] some mica, saturated
		38.0–40.0	4-5-6-6	Dark greenish gray SILT, trace fine sand, some mica, saturated
40		40.0–42.0	5-5-8-8	Dark greenish gray SILT, trace fine sand, some mica, trace rock fragments, saturated
		42.0–44.0	5-40/4"	Dark greenish gray SILT, trace fine sand, some mica, saturated
45		44.0		

GROUND WATER DATA:

WATER LEVEL IS ______ FT. BELOW GROUND SURFACE ______ HRS. AFTER COMPLETION.

Groundwater encountered @ 14'

HATCHER-SAYRE, INC.

* NO. OF BLOWS 140-LB. HAMMER, 30-IN. FALL REQUIRED TO DRIVE 2 IN. O.D., 1.375 IN I.D. SAMPLER 6 INCHES.

BORING LOG (CONTINUATION)

BORING NO.: RP-5 (B5M) PROJECT: Virginia Fibre Corporation Job No. 0300-004AA

DEPTH	STRATUM DESCRIPTION	SAMPLE DEPTH	SAMPLE BLOWS* CORE RECOVERY**	SAMPLE DESCRIPTION
45	GREENSTONE		Recovery=94% RQD = 88%	Light gray to gray, slightly weather GREENSTONE, some quartz, very hard, slightly fractured
50				
55			Recovery = 76% RQD = 74%	Same as above
60	Boring terminated @ 58.0'			
65				
70				
75				
80				
85				
90				
95				
100				

* NO. OF BLOWS 140-LB. HAMMER, 30-IN. FALL, REQUIRED TO DRIVE 2 IN. O.D., 1.375 IN I.D. SAMPLER 6 INCHES.

ROCK PIEZOMETER CONSTRUCTION LOG

MONITORING WELL: RP-5 JOB NO.: 0300-004AA DATE: 10/22&25/91

PROJECT: Virginia Fibre Corporation

SITE LOCATION: Amherst County, VA GEOLOGIST: JKS

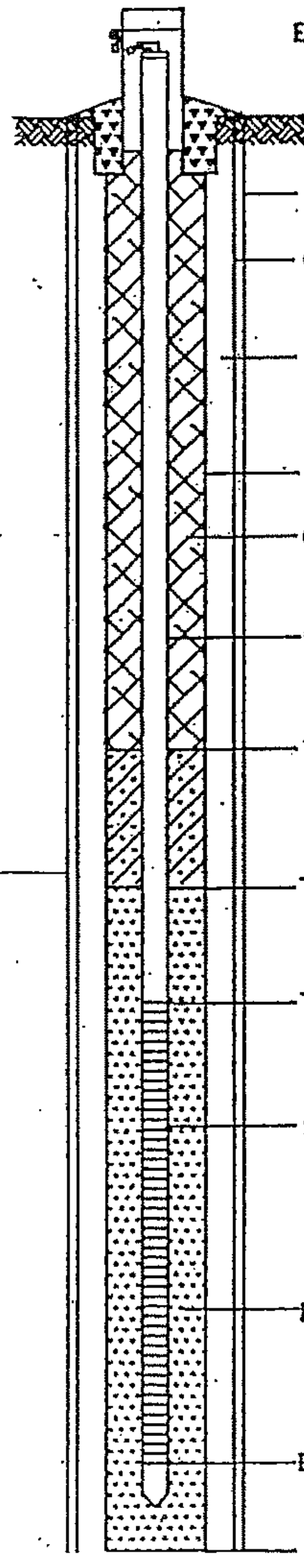
DRILLING CONTRACTOR: Fishburne Drilling Co., Inc.

HATCHER-SAYRE, INC.

GENERALIZED STRATIGRAPHY

SILT (ML)

ROCK



ELEVATIONS: GROUND SURFACE: 552.74
TOP OF CASING: 556.65
NOTCH: 556.14

DIAMETER OF BORING 0.67 FEET

GROUT TYPE: % BENTONITE 10
% CEMENT 90

CASING TYPE: MATERIAL PVC
SCHEDULE 40
INNER DIAMETER 0.33 FEET

DIAMETER OF BORING 0.24 FEET

GROUT TYPE: % BENTONITE 10
% CEMENT 90

CASING TYPE: MATERIAL PVC
SCHEDULE 40
INNER DIAMETER 0.16 FEET

TOP OF BENTONITE SEAL: DEPTH 43 FEE
ELEV. 509.74

TOP OF FILTER PACK: DEPTH 45 FEE
ELEV. 507.74

TOP OF SCREEN: DEPTH 46.3 FEE
ELEV. 506.44

SCREEN TYPE: MATERIAL PVC
SCHEDULE 40
INNER DIAMETER 0.16 FEET
SLOT SIZE 0.010

FILTER PACK TYPE: None.

BOTTOM OF SCREEN: DEPTH 56.3 FEE
ELEV. 496.44

BOTTOM OF BORING: DEPTH 58 FEE
ELEV. 494.74

BORING LOG

BORING NO.: RP-6	ELEVATION — TOP OF BORING: 565.02		DATE OF BORING: 8/29/91
PROJECT: Virginia Fibre Corp.			Job No. 0300-004 AA
LOCATION: Amherst, Virginia			
TYPE OF BORING: 6¼" I.D. Hollow-Stem Auger			OBSERVER: JKS
DRILLING CONTRACTOR: Fishburne Drilling, Inc., Chesapeake, Virginia			

DEPTH	STRATUM DESCRIPTION	SAMPLE DEPTH	SAMPLE BLOWS* CORE RECOVERY**	SAMPLE DESCRIPTION
0	SILT (ML)	0.0–2.0	15-16-11-13	Red SILT, trace clay, trace fine sand trace mica, trace root fragments, mois
		2.0–4.0	14-22-24-26	Reddish brown SILT, some mica, trace fine sand, moist
5		4.0–6.0	8-8-13-20	Same as above
		6.0–8.0	13-24-50/4"	Same as above
		8.0–10.0	8-14-16-18	Same as above
10		10.0–12.0	7-12-17-21	Same as above
		12.0–14.0	24-31-33-45	Brown SILT, trace fine sand, some mic: wet
15		14.0–16.0	25-33-33-37	Same as above
		16.0–18.0	35-36-35-42	Same as above
		18.0–20.0	9-16-19-24	Same as above
20		20.0–22.0	10-30-43-28	Same as above
		22.0–23.9	28-27-46-50/4"	Brown SILT, trace fine to coarse sand some mica, trace rock fragments, wet
25		24.0–25.4	16-42-50/5"	Brown SILT, trace fine sand, some mic: wet
		26.0–27.8	29-39-47-50/4"	Same as above
		28.0–29.5	22-45-51/6"	Brown SILT, trace fine to coarse sand some mica, wet
30		30.0–30.9	21-50/5"	Same as above
		32.0–34.0	16-27-26-28	Same as above
35	Quartz Fragments	34.0–36.0	30-24-36-45	Yellowish brown quartz fragments, saturated
	SILT (ML)	36.0–37.3	44-47-50/4"	Brown SILT, some fine sand, some mica wet
		38.0–38.7	54-50/2"	Same as above
40		40.0–40.3	50/4"	Brown SILT, some fine to coarse sand, some mica, trace rock fragments, wet
		42.0–42.3	50/4"	Same as above
45		44.0–44.3	50/4"	Same as above

GROUND WATER DATA:

WATER LEVEL IS ______ FT. BELOW GROUND SURFACE ______ HRS. AFTER COMPLETION.

No groundwater encountered

HATCHER-SAYRE, INC.

* NO. OF BLOWS 140-LB. HAMMER, 30-IN. FALL REQUIRED TO DRIVE 2 IN. O.D., 1.375 IN I.D. SAMPLER 6 INCHES.
** CORE RECOVERY AS PERCENT OF LENGTH OF DRILL RUN.
SEE NOTES TO BORING LOG WHICH ARE A PART OF THIS LOG

BORING LOG (CONTINUATION)

BORING NO.: RP-6 | PROJECT: Virginia Fibre Corp. | Job No. 300-004 AA

DEPTH	STRATUM DESCRIPTION	SAMPLE DEPTH	SAMPLE BLOWS* CORE RECOVERY**	SAMPLE DESCRIPTION
45	SILT	46.0	50/4"	Same as above
		46.5	35/0"	No sample retained
			Core Rec = 72% RQD = 30%	Brownish green weathered GREENSTONE, medium hardness, fractured
50				
	GREENSTONE			
55		55.0	Core Rec = 78% RQD = 77%	Light green to green slightly weathered GREENSTONE, very hard, slightly fractured, foliation near 60°
60	Boring terminated 60.0'	60.0		
65				
70				
75				
80				
85				
90				
95				
100				

* NO. OF BLOWS 140-LB. HAMMER, 30-IN. FALL, REQUIRED TO DRIVE 2 IN. O.D., 1.375 IN I.D. SAMPLER 6 INCHES.
** CORE RECOVERY AS PERCENT OF LENGTH OF DRILL RUN.

HATCHER-SAYRE, INC.

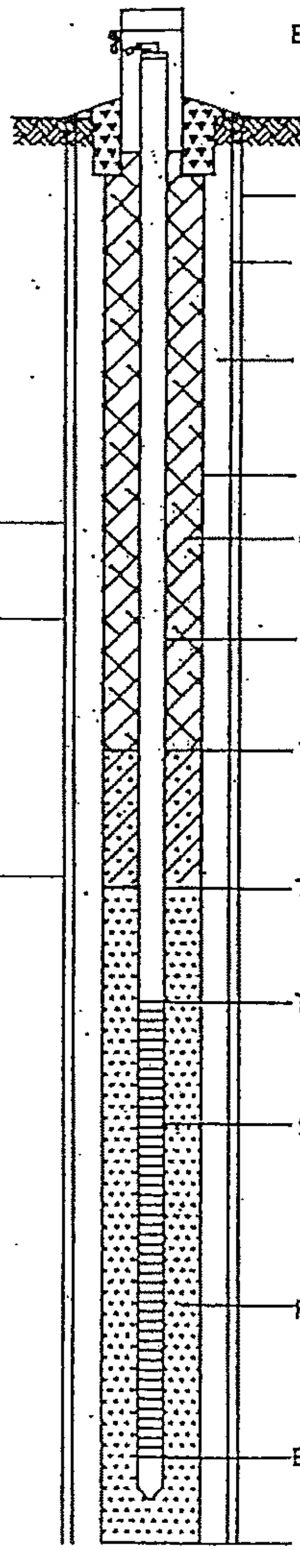
ROCK PIEZOMETER CONSTRUCTION LOG

ROCK PIEZOMETER: RP-6 JOB NO.: 0300-004AA DATE: 9/6/91
PROJECT: Virginia Fibre Corp. - New Landfill
SITE LOCATION: Amherst Co., VA GEOLOGIST: JKS
DRILLING CONTRACTOR: Fishburne Drilling Company, Inc.

HATCHER-SAYRE, INC.

GENERALIZED STRATIGRAPHY

Generalized Stratigraphy
SILT
Quartz Fragments
SILT
Rock



ELEVATIONS: GROUND SURFACE: 565.02
TOP OF CASING: 568.29
NOTCH: 566.96

DIAMETER OF BORING 0.67 FEET

GROUT TYPE: % BENTONITE 10
% CEMENT 90

CASING TYPE: MATERIAL PVC
SCHEDULE 40
INNER DIAMETER 0.33 FEET

DIAMETER OF BORING 0.24 FEET

GROUT TYPE: % BENTONITE 10
% CEMENT 90

CASING TYPE: MATERIAL PVC
SCHEDULE 40
INNER DIAMETER 0.17 FEET

TOP OF BENTONITE SEAL: DEPTH 43.5 FEET
ELEV. 521.52

TOP OF ROCK: DEPTH 46.5 FEET
ELEV. 518.52

TOP OF SCREEN: DEPTH 48.0 FEET
ELEV. 517.02

SCREEN TYPE: MATERIAL PVC
SCHEDULE 40
INNER DIAMETER 0.17 FEET
SLOT SIZE 0.010

FILTER PACK TYPE: None

BOTTOM OF SCREEN: DEPTH 58.0 FEET
ELEV. 507.02

BOTTOM OF BORING: DEPTH 58.0 FEET
ELEV. 507.02

BORING LOG

BORING NO.: RP-7	ELEVATION — TOP OF BORING: 610.87	DATE OF BORING: 9/5/91 & 9/6/91	
PROJECT: Virginia Fibre Corp.		Job No. 0300-004 AA	
LOCATION: Amherst, Virginia			
TYPE OF BORING: 6¼" I.D. Hollow-Stem Auger		OBSERVER: JKS	
DRILLING CONTRACTOR: Fishburne Drilling, Inc., Chesapeake, Virginia			

DEPTH	STRATUM DESCRIPTION	SAMPLE DEPTH	SAMPLE BLOWS* CORE RECOVERY**	SAMPLE DESCRIPTION
0	SILT (ML)	0.0 – 2.0	6-6-6-8	Red SILT, trace fine sand, some mica, trace root fragments, moist
		2.0 – 4.0	12-10-12-11	Same as above
5		4.0 – 6.0	8-8-12-14	Same as above
		6.0 – 8.0	16-18-23-29	Brown SILT, trace fine sand, some mica, moist
10		8.0 – 10.0	4-8-16-31	Same as above
		10.0 – 12.0	12-24-32-30	Same as above
		12.0 – 14.0	29-34-44-44	Same as above
15		14.0 – 16.0	8-15-23-27	Same as above
		16.0 – 18.0	24-36-36-48	Same as above
20		18.0 – 20.0	10-20-52-37	Same as above
		20.0 – 22.0	6-18-25-34	Same as above
		22.0 – 24.0	34-46-42-41	Brown SILT, trace fine sand, some mica, trace rock fragments, moist
25		24.0 – 25.4	6-36-60/5"	Same as above
		26.0 – 26.7	46-55/2.5"	Same as above
		28.0 – 28.6	40-50/1"	Same as above
30		30.0 – 30.1	50/1"	No sample retained
		32.0 – 33.4	13-32-50/5"	Brown SILT, trace fine sand, some mica, trace rock fragments, moist
35		34.0 – 34.8	52-50/4"	Same as above
		36.0 – 36.2	50/2.5"	No sample retained
	Quartz Fragments	38.0 – 38.4	50/5"	Yellowish brown quartz fragments, some mica, moist
40	SILT (ML)	40.0 – 40.3	50/4"	No sample retained
		42.0 – 42.8	29-50/4"	Brown SILT, some rock fragments, some mica, moist
45		44.0 – 44.1	50/1"	No sample retained

GROUND WATER DATA:

WATER LEVEL IS ______ FT. BELOW GROUND SURFACE ______ HRS. AFTER COMPLETION.

No groundwater encountered

HATCHER-SAYRE, INC.

* NO. OF BLOWS 140-LB. HAMMER, 30-IN. FALL, REQUIRED TO DRIVE 2 IN. O.D., 1.375 IN I.D. SAMPLER 6 INCHES.
** CORE RECOVERY AS PERCENT OF LENGTH OF DRILL RUN.
SEE NOTES TO BORING LOG WHICH ARE A PART OF THIS LOG.

BORING NO.: RP-7 PROJECT: Virginia Fibre Corp. Job No. 0300-004 AA

DEPTH	STRATUM DESCRIPTION	SAMPLE DEPTH	SAMPLE BLOWS* CORE RECOVERY**	SAMPLE DESCRIPTION
45	SILT (ML)	46.0 46.2	50/1"	No sample retained
		48.0 48.3	50/2.5"	No sample retained
50		50.0 50.3	50/4"	No sample retained
	GREENSTONE	52.0	Core Rec = 40% RQD = 10%	Brownish green, highly weathered GREENSTONE, medium hardness, fractured
55				
60		59.0	Core Rec = 25% RQD = 0%	Same as above
65	Boring terminated @ 65.0'	65.0		
70				
75				
80				
85				
90				
95				
100				

* NO. OF BLOWS 140-LB. HAMMER, 30-IN. FALL, REQUIRED TO DRIVE 2 IN. O.D., 1.375 IN I.D. SAMPLER 6 INCHES.
** CORE RECOVERY AS PERCENT OF LENGTH OF DRILL RUN.

HATCHER-SAYRE, INC.

ROCK PIEZOMETER CONSTRUCTION LOG

ROCK PIEZOMETER: RP-7 JOB NO. : 0300-004AA DATE : 9/6/91

PROJECT : Virginia Fibre Corp. - New Landfill

SITE LOCATION: Amherst Co., VA GEOLOGIST : JKS

DRILLING CONTRACTOR : Fishburne Drilling Company, Inc.

HATCHER-SAYRE, INC.

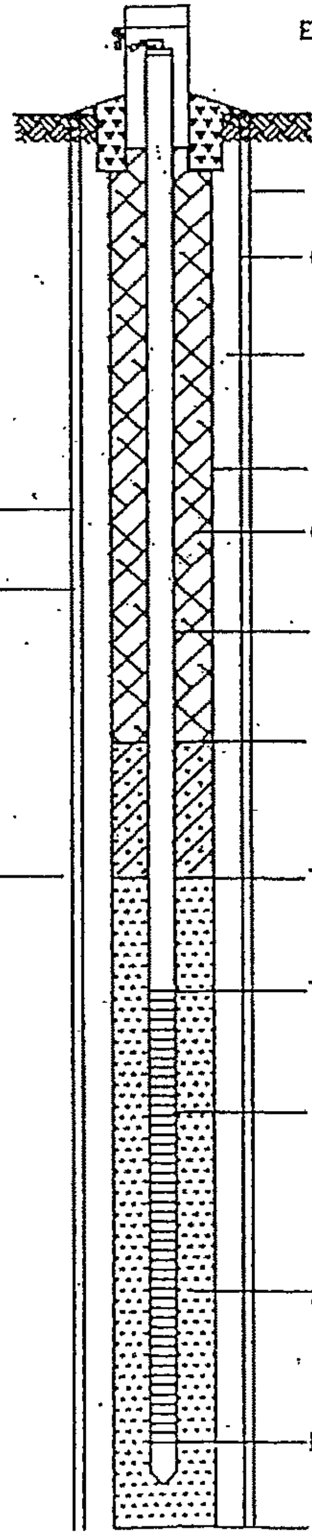
GENERALIZED STRATIGRAPHY

SILT

Quartz Fragments

SILT

Rock



ELEVATIONS : GROUND SURFACE : 610.87
TOP OF CASING : 613.71
NOTCH : 612.68

DIAMETER OF BORING 0.67 FEET

GROUT TYPE : % BENTONITE 10
% CEMENT 90

CASING TYPE : MATERIAL PVC
SCHEDULE 40
INNER DIAMETER 0.33 FEET

DIAMETER OF BORING 0.24 FEET

GROUT TYPE : % BENTONITE 10
% CEMENT 90

CASING TYPE : MATERIAL PVC
SCHEDULE 40
INNER DIAMETER 0.17 FEET

TOP OF BENTONITE SEAL : DEPTH 49 FEET
ELEV. 561.87

TOP OF ROCK : DEPTH 52 FEET
ELEV. 558.87

TOP OF SCREEN : DEPTH 53.7 FEET
ELEV. 557.17

SCREEN TYPE : MATERIAL PVC
SCHEDULE 40
INNER DIAMETER 0.17 FEET
SLOT SIZE 0.010

FILTER PACK TYPE : None

BOTTOM OF SCREEN : DEPTH 63.7 FEET
ELEV. 547.17

BOTTOM OF BORING : DEPTH 64.2 FEET
ELEV. 546.67

APPENDIX 5

FIELD PROCEDURES: TABLES / FORMS

CHAIN OF CUSTODY

CLIENT:	CONSULTANT:	COPY COA TO CONSULTANT?
ATTN:	ATTN:	COPY INVOICE TO CONSULTANT?
STREET:	STREET:	FACILITY:
CITY:	CITY:	LOCATION:
PHONE:	PHONE:	LAB JOB NO:
TURN AROUND: standard	JOB NO.	ANALYSES REQUESTED

LAB USE ONLY	SAMPLE INFORMATION			COMP	GRAB	NO. OF JARS	MATRIX											COMMENTS
LAB ID	**SAMPLE ID**	**DATE**	**TIME**															

SAMPLED BY:	PRINTED NAME:	NOTES:

RELINQUISHED BY:	DATE	TIME	RECEIVED BY:	DATE	TIME	REASON FOR TRANSPORT

TEMP:	pH:	CONTENTS: S=SOIL; G=GROUNDWATER; WW=WASTEWATER

VSWMR TABLE 3.1 COLUMN B CONSTITUENTS SAMPLE STORAGE AND PRESERVATION PROTOCOLS[1]			
PARAMETER	**CONTAINER/ VOLUME REQUIRED**	**PRESERVATIVE**	**MAXIMUM HOLDING TIME**
INORGANIC TESTS			
Cyanide	P, G - 500 ml	Cool to 4°C, NaOH to pH>12, 0.6 g ascorbic acid.	14 days
Sulfide	P, G - 500 ml	Cool to 4°C, add Zinc acetate	7 days
METALS TESTS			
Mercury (total)	P - 300 ml	HNO_3 to pH<2	28 days
Metals (total) except Mercury and Chromium VI	P - 1 L	HNO_3 to pH<2	6 months
ORGANIC TESTS			
Acrolein and acrylonitrile	2 - 40 ml VOA[3] w/ G, Teflon-lined septum	Cool to 4°C, 0.008% $Na_2S_2O_3$, adjust pH to 4-5	14 days
Benzidines	G, Teflon-lined cap - 1 L	Cool to 4°C, 0.008% $Na_2S_2O_3$, adjust pH to 4-5	7 days until extraction; 40 days after extraction
Haloethers	G, Teflon-lined cap - 1 L	Cool to 4°C, 0.008% $Na_2S_2O_3$	7 days until extraction; 40 days after extraction
Phthalate esters	G, Teflon-lined cap - 1 L	Cool to 4°C	7 days until extraction; 40 days after extraction
Nitrosamines	G, Teflon-lined cap - 1 L	Cool to 4°C, store in dark, 0.008% $Na_2S_2O_3$	7 days until extraction; 40 days after extraction
Nitroaromatics and cyclic ketones	G, Teflon-lined cap - 1 L	Cool to 4°C, store in dark, 0.008% $Na_2S_2O_3$	7 days until extraction; 40 days after extraction
PCBs	G, Teflon-lined cap - 1 L	Cool to 4°C	7 days until extraction; 40 days after extraction
Phenols	G, Teflon-lined cap - 1 L	Cool to 4°C, 0.008% $Na_2S_2O_3$	7 days until extraction; 40 days after extraction
Purgeable Aromatic Hydrocarbons	2 - 40 ml VOA[3] G, Teflon-lined septum	Cool to 4°C, 0.008%, $Na_2S_2O_3$, HCL to pH2	14 days
Purgeable Halocarbons	2 - 40 ml VOA[3] w/ G, Teflon-lined septum	Cool to 4°C, 0.0008% $Na_2S_2O_3$	14 days
Polynuclear aromatic hydrocarbons	G, Teflon-lined cap - 1 L	Cool to 4°C, 0.008% $Na_2S_2O_3$. Store in dark.	7 days until extraction; 40 days after extraction
Chlorinated hydrocarbons	G, Teflon-lined cap - 1 L	Cool to 4°C	7 days until extraction; 40 days after extraction
PESTICIDES TESTS			
Pesticides	G, Teflon-lined cap - 1 L	Cool to 4°C. pH 5-9	7 days until extraction; 40 days after extraction

1 - Test Methods for Evaluating Solid Waste - Physical/Chemical Methods, SW-846, latest edition
2 - P - Plastic, G - Glass, T - Fluorocarbon Resin (PTFE, Teflon, FEP, etc.)
3 - Do not allow any head space in VOA container.
4 - Shipping containers should be certified as to 4°C temperature at time of sample placement into these containers. Preservation of samples requires the temperature of collected samples be adjusted to 4°C immediately after collection.
5 - Based on regulatory requirements, the volume collected must be sufficient to allow for the analysis on each parameter.

CLIENT: GREIF PACKAGING LLC
FACILITY: INDUSTRIAL LANDFILL
LOCATION: RIVERVILLE, AMHERST COUNTY, VIRGINIA
PROJECT: GROUNDWATER MONITORING PROGRAM
TASK: EVENT ABCD

FIELD SAMPLING FORM

SAMPLING DATE: XX-YY-ZZ

Project no.	Personnel:	Weather:

Order in which wells were sampled:

Equipment:

constituent / parameter	container	preservative

Comments:

Signature:

CLIENT: GREIF PACKAGING LLC
FACILITY: INDUSTRIAL LANDFILL
LOCATION: RIVERVILLE, AMHERST COUNTY, VIRGINIA
PROJECT: GROUNDWATER MONITORING PROGRAM

STANDARD PURGE GOALS

DATE OF SAMPLING EVENT: XX-YY-ZZ

Well	DTW $_m$ (ft)	TD $_{m\ (ft)}$	purge goal (gal)	3 well volumes (gal)
MW-01		80.48	Low Flow	
MWB-01		56.93	Low Flow	
B-12		23.21	Low Flow	
MW-05		38.35	Low Flow	
MW-06		44.82	Low Flow	
MW-07		53.27	Low Flow	
MW-08		79.99	Low Flow	

DTW m (ft) = measured depth-to-water (relative to reference point)

TD m (ft) = measured well depth (relative to reference point)

CLIENT: GREIF PACKAGING LLC
FACILITY: INDUSTRIAL LANDFILL
LOCATION: RIVERVILLE, AMHERST COUNTY, VIRGINIA
PROJECT: GROUNDWATER MONITORING PROGRAM
TASK: EVENT ABCD

PURGE DATA

DATE: XX-YY-ZZ

WELL: MW-01

VOLUME (GAL.)	DTW (feet)	TIME	pH (S.U.)	CONDUCTIVITY (μS)	TEMPERATURE (^{o}C)	D.O. (mg/l)	ORP (mV)	TURBIDITY (NTU)
START								
SAMPLE								

all parameters measured with Horiba Water Quality Meter

well purged and sampled with portable pump

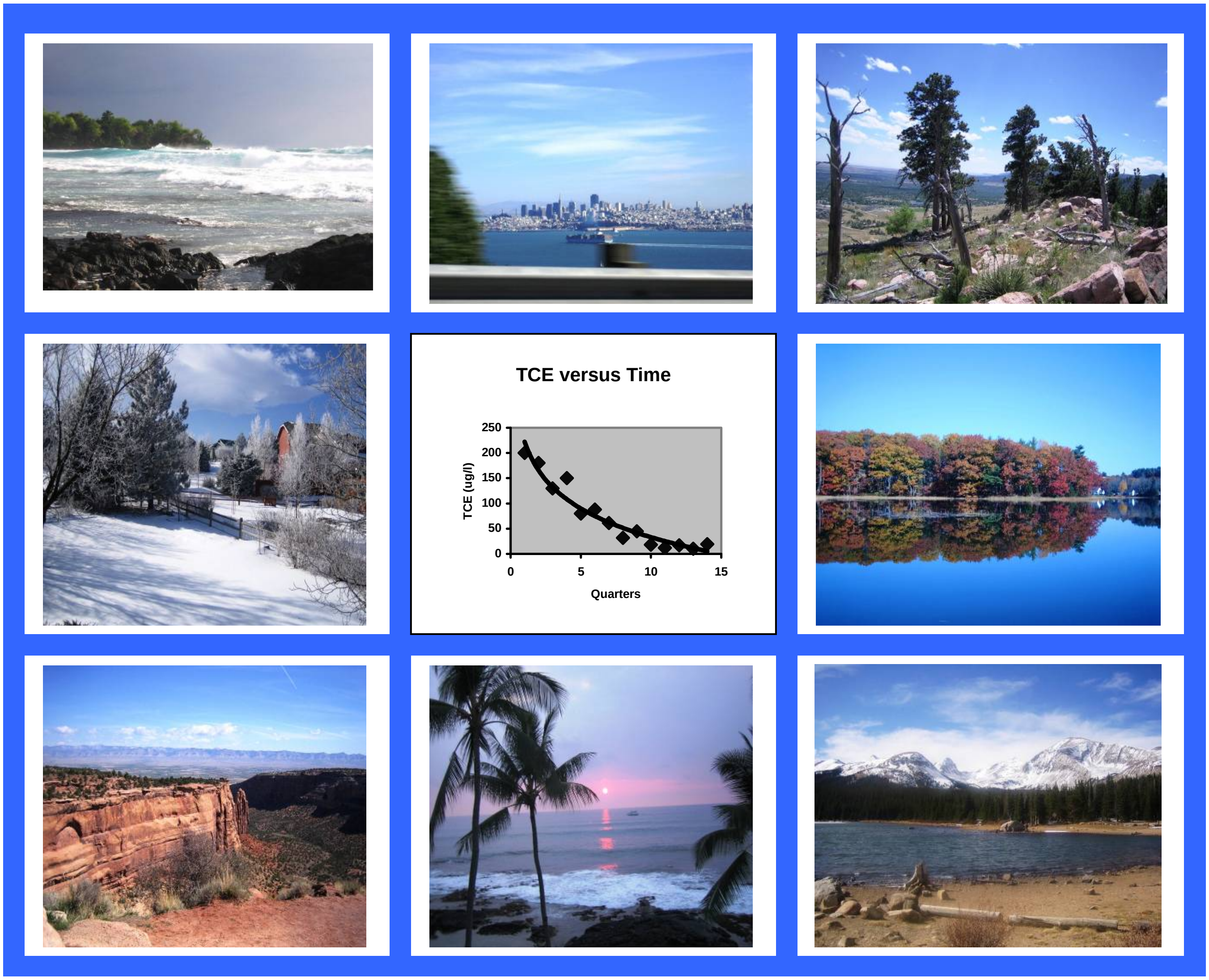
APPENDIX 6

DATA ANALYSIS FOR SOLID WASTE FACILITIES

STATISTICAL ANALYSIS OF GROUNDWATER MONITORING DATA AT RCRA FACILITIES

UNIFIED GUIDANCE MARCH 2009

EPA 530/R-09-007



ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RESOURCE CONSERVATION AND RECOVERY

STATISTICAL ANALYSIS OF GROUNDWATER MONITORING DATA AT RCRA FACILITIES

UNIFIED GUIDANCE

OFFICE OF RESOURCE CONSERVATION AND RECOVERY

PROGRAM IMPLEMENTATION AND INFORMATION DIVISION

U.S. ENVIRONMENTAL PROTECTION AGENCY

MARCH 2009

EPA 530/R-09-007a

ERRATA SHEET —MARCH 2009 UNIFIED GUIDANCE

August 9, 2010

The following are corrections made to a number of Example calculations and equations in the March 2009 Unified Guidance [*EPA 530/R-09-007*]:

Chapter 10, Example 10-1: In the initial table of Nickel concentrations, 'Years' has been changed to 'Wells' to maintain consistency with succeeding examples. At the bottom of page 10-11, the following sentence was added (to allow for pooling): "Assume that the individual well data sets can be shown to arise from a single common population."

Chapter 10, Example 10-4 Calculations for the Multiple Group Shapiro-Wilk Test (full revised example text in parentheses):

"The previous examples in this chapter pooled the data of **Example 10-1** into a single group before testing for normality. This time, treat each well separately and compute the Shapiro-Wilk multiple group test of normality at the $\alpha = .05$ level.

SOLUTION

Step 1. The nickel data in **Example 10-1** come from $K = 4$ wells with $n_i = 5$ observations per well. Using equation [10.10], the SW_i individual well test statistics are calculated as:

Well 1: $SW_1 = 0.7577$
Well 2: $SW_2 = 0.7396$
Well 3: $SW_3 = 0.7065$
Well 4: $SW_4 = 0.8149$

Step 2. Since $n_i = 5$ for each well, use **Table 10-7** of **Appendix D** to find $\varepsilon = .5521$. First calculating u_1 with equation [10.20]:

$$u_1 = \ln\left(\frac{.7577-.5521}{1-.7577}\right) = -.1641$$

Then performing this step for each well group and using linear interpolation on u in **Table 10-7**, the approximate G_i statistics are:

Well 1:	$u_1 = -.1641$	$G_1 = -1.783$
Well 2:	$u_2 = -.3280$	$G_2 = -1.932$
Well 3:	$u_3 = -.6425$	$G_3 = -2.200$
Well 4:	$u_4 = \ \ .3502$	$G_4 = -1.254$

Step 3. Compute the multiple group test statistic using equation [10.21]:

$$G = \frac{1}{\sqrt{4}}\left[(-1.783)+(-1.932)+(-2.200)+(-1.254)\right] = -3.585$$

Step 4. Since $\alpha = 0.05$, the lower $\alpha \times 100th$ critical point from the standard normal distribution in **Table 10-1** of **Appendix D** is $z_{.05} = -1.645$. Clearly, $G < z_{.05}$; in fact G is equivalent to a Z-value probability of .0002. Thus, there is significant evidence of non-normality in at least one of these wells (and perhaps all of them). ◄ “

<u>Chapter 12, Example 12-1 Calculations for Screening with Probability Plots</u>

In Figures 12-1 through 12-4 and the accompanying text, normality correlation coefficients have been adjusted (using the method in UG Section 10.6) as follows:

Figure 12-1 Raw Correlation Coefficient (N =20) -- .502

Figure 12-2 Log " " (N =20) -- .973

Figure 12-3 Raw " ", 1 outlier removed (N = 19) -- .854

Figure 12-4 Log " ", 1 outlier removed (N = 19) -- .987

<u>Chapter 13, Example 13-1 Tables of Iron Concentrations</u>

p.13-3. The median should be 50.06 ppm for Well 1; for Well 2, the mean is 55.74 ppm.

For comparative purposes, well sample standard deviations have been added at the bottom of this table: Well 1—12.40; Well 2—20.34; Well 3—59.35; Well 4—25.95; Well 5—92.16; and Well 6—51.20 ppm

p.13-4 (log iron concentration table) The median for Well 1 is 3.91 log(ppm). Sample well log standard deviations are already found in the table on page 13-7.

Chapter 13, Example 13-2 ANOVA Calculations for Log Iron Concentrations (full revised example text in parentheses):

" SOLUTION

Step 1. With 6 wells and 4 observations per well, $n_i = 4$ for all the wells. The total sample size is $n = 24$ and $p = 6$. Compute the (overall) grand mean and the sample mean concentrations in each of the well groups using equations [17.1] and [17.2]. These values are listed (along with each group's standard deviation) in the above table.

Step 2. Compute the sum of squares due to well-to-well differences using equation [17.3]:

$$SS_{wells} \quad = \quad \left[4(3.820)^2 + 4(3.965)^2 + \quad \ldots \quad + 4(5.000)^2\right] - 24(4.354)^2 \quad = 4.331$$

This quantity has (6 – 1) = 5 degrees of freedom.

Step 3. Compute the corrected total sum of squares using equation [17.4] with $(n - 1) = 23$ df:

$$SS_{total} \quad = \quad \left[(4.06)^2 + \quad \ldots \quad + (5.08)^2\right] - 24(4.354)^2 \quad = 8.935$$

Step 4. Obtain the within-well or error sum of squares by subtraction using equation [17.5]:

$$SS_{error} = 8.935 - 4.331 = 4.604$$

This quantity has $(n - p) = 24–6 = 18$ degrees of freedom.

Step 5. Compute the well and error mean sum of squares using equations [17.6] and [17.7]:

$$MS_{wells} = 4.331 / 5 = .866$$

$$MS_{error} = 4.604 / 18 = .256$$

Step 6. Construct the *F*-statistic and the one-way ANOVA table, using **Figure 13-3** as a guide:

Source of Variation	Sums of Squares	Degrees of Freedom	Mean Squares	*F*-Statistic
Between Wells	4.331	5	0.866	F = 0.866/0.256=3.38
Error (within wells)	4.604	18	0.256	
Total	8.935	23		

Step 7. Compare the observed F-statistic of 3.38 against the critical point taken as the upper 95th percentage point from the F-distribution with 5 and 18 degrees of freedom. Using **Table 17-1** of **Appendix D**, this gives a value of $F_{.95,5,18}$ = 2.77. Since the F-statistic exceeds the critical point, the null hypothesis of equal well means can be rejected, suggesting the presence of significant spatial variation. ◄ "

Chapter 13, Example 13-3 ANOVA Pooled Variance Used for Prediction Limit Calculations for Log Iron Concentrations

With the slight modification in $\sqrt{MS_{error}} = \sqrt{.256} = .506$ from Example 13.2, as shown in Step 2 p.13-11, the resulting table with well-specific prediction limits is changed to:

	Adjusted 99% Prediction Limits for Iron (ppm)					
	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6
Log-mean	3.820	3.965	4.348	4.188	4.802	5.000
RMSE	0.5079	0.5079	0.5079	0.5079	0.5079	0.5079
df	18	18	18	18	18	18
$t_{.99,18}$	2.552	2.552	2.552	2.552	2.552	2.552
99% PL	193.2	223.3	327.5	279.1	515.8	628.7

Chapter 14, Section 14.2.2 Procedure for Estimating Sample Size for a prediction limit with significant temporal variation, Step 9 (modifies equations for total events):

" Step 9. If there is no spatial variability but a significant temporal effect exists among a set of background wells, compute an appropriate *interwell* prediction or control chart limit as follows. First replace the background sample standard deviation (s) with the following estimate built from the one-way ANOVA:

$$\hat{\sigma} = \sqrt{\frac{1}{W}\left[MS_T + (W-1)\,MS_E\right]} \qquad [14.12]$$

Then calculate the effective sample size for the prediction limit as:

$$n^* = 1 + \left\{\left[TK \cdot (TK-1) \cdot (F_T + W - 1)^2\right] \big/ \left[TK \cdot F_T^2 + (TK-1)\cdot(W-1)\right]\right\} \qquad [14.13] \text{ "}$$

Chapter 14, Example 14-2, Steps 5, 7 and 8:

Although the final calculation is correct, the value for (W-1) in equation [14.7] is 3, not 7:

" Step 5. Compute the mean error sum of squares term using equation [14.7]:

$$MS_E \;=\; \left[(-1.150)^2 + (-.780)^2 + \ldots + (1.338)^2 + (-.765)^2\right] \big/ (4\cdot 2)(3) \;=\; 1.87 \text{ "}$$

The corrected degrees of freedom language in Step 7 is:

" Step 7. Test for a significant temporal effect, computing the F-statistic in equation [14.11]:

$$F_T = 7.55/1.87 = 4.04$$

The degrees of freedom associated with the numerator and denominator respectively are (TK–1) = 7 and $TK(W$–1) = 24. Just as with Levene's test run earlier, the 5% level critical point for the test is $F_{.95,7,24}$ = 2.42. Since F_T exceeds this value, there is evidence of a significant temporal effect in the manganese background data. "

In Step 8, the estimated adjusted standard deviation is:

$$\hat{\sigma} = \sqrt{\frac{1}{4}\left[7.55 + 3\cdot(1.87)\right]} = 1.814\ ppm$$

Chapter 14, Example 14-7, Step 2:

Although the final calculation is correct, the value for N_e should be a decimal:

" Step 2. To estimate the minimum time interval between sampling events enabling the collection of physically independent samples of ground water, calculate the horizontal component of the average linear groundwater velocity (V_h) using Darcy's equation [14.17]. With K_h = 15 ft/day, Ne = .15 (15%), and i = 0.003 ft/ft, the velocity becomes:

$$V_h = (15\ ft/day \times .003\ ft/ft)/.15 = .3\ ft/day\ or\ 3.6\ in/day$$ "

Chapter 16, Example 16-3, Shapiro-Wilk Calculations in Steps 1 and 2:

The G multiple group value in Step 1 is -6.671 using original benzene data. The corresponding value for the log transformed data is G = -.512 in Step 2. Other results are correct.

Chapter 17, Example 17-6, Mann-Kendall Test Calculations, Steps 2 & 3:

In Step 2, the Mann-Kendall statistic S =194, not 196. The standard deviation calculation of 37.79 in Step 3 is correct. The modified S changes the Z-approximation to 5.11 in Step 3:

$$Z = (|194| - 1)/37.79 = 5.11$$

Chapter 18, Example 18-2, Statistics in Table, and Step 2:

The joint well log mean for chrysene is 2.553, not 2.533 ppb. This changes the future mean prediction limit calculation in Step 2:

$$PL = 2.553 + (2.998)(.706)\sqrt{\frac{1}{4}+\frac{1}{8}} = 3.85 \log((ppb)$$

Chapter 19, Example 19-2, Step 4:

The median value of the initial three data for well CW-2 is .36, not .41 ppb. Other results are not affected.

Chapter 21, Example 21-7, Step 4:

The correct value for (n-1) in the denominator should be 9, not 8 as applied with equation [21.25]. This changes the UCL calculation results as follows:

" Step 4. Since the comparison to the GWPS of 20 ppb is to be made at the $\alpha = 0.05$ significance level, the confidence limit is $(1–\alpha) = 95\%$ confidence. Since the remediation effort aims to demonstrate that the true mean TCE level has dropped below 20 ppb, a one-way UCL needs to be determined using equation [21.25]. A logical point along the trend to examine is the last sampling event at $t_0 = 30$. Using the estimated regression value at $t_0 = 30$, and the fact that $F_{.90,2,8} = 3.1131$, the UCL on the mean TCE concentration at this point becomes:

$$UCL_{95} = 6.861 + \sqrt{2 \times 15.60 \times 3.1131 \times \left[\frac{1}{10} + \frac{(30-15.3)^2}{9 \times 88.2333}\right]} = 12.87\ ppb$$

Since this upper limit is less than the GWPS for TCE, conclude that the remediation goal has been achieved by $t_0 = 30$. In fact, other times can also be tested using the same equation. At the next to last sampling event ($t_0 = 26$), the UCL is:

$$UCL_{95} = 13.272 + \sqrt{2 \times 15.60 \times 3.1131 \times \left[\frac{1}{10} + \frac{(26-15.3)^2}{9 \times 88.2333}\right]} = 18.14\ ppb \text{ ``}$$

VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY

TECHNICAL PAPER: DATA ANALYSIS FOR SOLID WASTE FACILITIES

.
The purpose of this document is to address common questions for the solid waste staff pertaining to the statistical analysis of groundwater samples at solid waste facilities. This document should be used in conjunction with the groundwater monitoring and sampling analysis plan. The statistical methods covered in this document include the most common statistical analyses used for groundwater monitoring samples at solid waste sites. For additional details, please refer to the EPA guidance documents listed on page 7 of this document.

INTRODUCTION

Statistical analysis of the groundwater data presented in monitoring reports for submission to the Virginia Department of Environmental Quality (VADEQ), Division of Waste Coordination should address the following:

A. Design of experiment
B. Outliers
C. Missing data
D. Evaluation of data below detection limits or quantitation limits
E. Checking assumptions (distributions, homogeneity of variances)
F. Selection of statistical method
G. Verification sampling strategy

A. DESIGN OF EXPERIMENT

The results of the statistical analysis can tell you only what the experiment was designed to explain. For example, up-gradient to down-gradient statistical comparisons will indicate if groundwater concentrations for a particular constituent are different up gradient of the landfill compared to down gradient of the landfill. This difference could be due to the landfill or due to natural site conditions. The facility must ensure that the design of the monitoring network and statistical experiment are designed to be able to detect a release of solid waste constituents from the landfill.

The facility should address natural spatial variation of groundwater constituents at a site when designing the monitoring network and type of statistical comparisons which will be performed. Two acceptable ways of dealing with spatial variability are to perform intra-well statistical comparisons only or to install additional up gradient or side gradient wells to account for natural variations at the site. If the facility possesses reliable pre-waste data (which have not been impacted by site activities) or can adequately demonstrate that inorganic constituent concentrations in wells which are located down gradient from the landfill have not been impacted by site activities, the facility may petition the VADEQ for a variance from inter-well statistical comparisons. The variance petition should be written in accordance with 9 VAC 20-80-750 (Virginia Solid Waste Management Regulations (VSWMR)) and include hydro-geologic information about the site, a demonstration that inorganic constituent concentrations in down gradient wells have not been impacted by the landfill, information regarding the date waste was originally placed in the landfill, and the best estimate possible of groundwater flow at the site. If the facility is an older site, or it cannot be determined that inorganic constituent concentrations in groundwater from wells located down gradient of the landfill are not impacted by the landfill activities, the facility can install additional up gradient (or side gradient) wells to attempt to get a better estimate of natural variation at the site. Please note that the location of the additional up gradient or side gradient wells must be approved by VADEQ permitting staff.

The facility should also determine the number of background samples which will be necessary for the planned statistical analysis method and ensure that an adequate number of samples have been collected prior to the statistical comparisons required by the VSWMR. The facility should collect an adequate number of background dataset for inter-well statistical comparisons within one year, and an adequate number of background samples for intra-well statistical comparisons within two years. Background for inter-well statistical comparisons can be updated with each sampling event, unless there is an indication that background wells have been impacted by the landfill. Background for intra-well statistical comparisons can be updated every two years, unless there is indication of a release in the down gradient well. Please note that for intra-well comparison a two-year time window should be left between background for intra-well comparisons and compliance samples to ensure that samples associated with a slow release are not included in the background dataset.

The facility must sample for all constituents required by the VSWMR, unless it has been specified in the permit or a variance granted by the VADEQ that a facility may sample for constituents other than the full list required by the VSWMR.

B. OUTLIERS

Inconsistently large or small values (outliers) can be observed due to errors from sampling, laboratory, transportation, transcription, or actual extreme values. The historical background dataset should be screened for each well and constituent for the existence of outliers (USEPA 1992, section 6.2) using the method described by Dixon (1953) or another method approved by the VADEQ. Background observations, which are considered to be outliers, should not be included in the statistical analysis to preserve the power of the test to detect a release from the facility. If an extreme value occurs in compliance well during the compliance sampling event, the facility should collect a re-sample within the compliance period of the initial sample. This will enable the VADEQ to distinguish between an extreme value in a compliance well and an indication of a release from the facility. Background observations should be evaluated to determine if data is normally distributed prior to running the outlier test.

C. Missing Data

If a sampling event results in a missing data value, an attempt to re-sample for the missing value should be made within the compliance period of the initial sampling event. It is recommended that the re-sample be collected as close to the initial sampling event as possible to minimize the effects of variation due to the differences in sample collection time and to allow additional time for a verification sample if one is needed.

D. Data Below Detection Limits

The facility should use laboratory derived limits of detection and quantitation in the statistical analyses of groundwater data, as opposed to the detection and quantitation limits which have been published for a particular analytical method.

For data where the percentage of data below the laboratory limit of detection or laboratory limit of quantitation is less than 25 percent, the facility should replace the non-detects or non-quantified values with half the laboratory limit of detection or quantitation. However, when the percentage of non-detects or non-quantified values is greater than 25 percent and less than 50 percent, the mean and standard deviation should be adjusted using either Aitchison’s adjustment (USEPA 1992 section 2.2.2 and Aitchison, 1955) or Cohen's adjustment (USEPA 1989 section 8.1.3 and Cohen, 1961). Extensive tables and computational details for Cohen’s adjustment are also provided in Gibbons, 1994a. The approach for selection between the two methods is described in USEPA (1992) section 2.2.1.

E. Checking Assumptions Associated with the Test Method

Parametric statistical test methods assume that the data follow a certain distribution, for groundwater statistics the distributions usually are the normal and the log-normal distributions. The facility must verify that the distributional assumptions of a particular test method are valid prior to applying the statistical test method.

No testing of normality is needed when the percentage of non-detects or non-quantified values is greater than 50%, since a non-parametric statistical test method should be applied. Most parametric statistical tests for environmental data will assume the data are normally or log-normally distributed. The Shapiro-Wilk test, multiple group Shapiro-Wilk test or Filliben’s correlation coefficient test should be applied to the dataset to determine the distributional form. To test for log-normality, the natural logarithms of the original data should be taken and tested for normality. The facility may use any other appropriate method for testing the distributional assumptions with approval by the VADEQ.

When the detection frequency is less than 50% or transformation fails to bring about normality, a non-parametric method should be used.

Non-parametric two- or multi-sample comparisons, such as the Wilcoxon rank sum test or the Kruskal-Wallis test assume that the dispersion for each group in the comparison is similar. This can be checked by comparing boxplots of each group.

F. SELECTION OF STATISTICAL METHOD

The facility should apply an appropriate statistical method consistent with the Virginia Solid Waste Management Regulations, 9 VAC 20-80-300.D.

Two- or Multi- Sample Comparisons

If a facility chooses to perform statistical comparisons using a two- or multi-way statistical test method (i.e. t-test, ANOVA, Wilcoxon rank sum, Kruskal-Wallis), the facility will need to collect a minimum of four samples per compliance period. As specified in the VSWMR the level of significance when performing these tests for individual well comparison shall be no less than 0.01 and no less than 0.05 for multiple comparisons. Due to the number of samples which need to be collected per compliance period most facilities prefer to apply the interval methods for statistical analysis associated with a compliance sampling event. However, when the intent of the statistical analysis is to show that mean/median concentration levels are similar between the background and compliance area (i.e. a first determination for an industrial or CDD landfill) the two- or multi-sample comparison statistical methods can be useful.

The facility should check distributional assumptions for both background and compliance datasets and check assumptions of homogeneity of variances prior to applying these tests.
The ANOVA test assumes data are normally or log-normally distributed and variances are homogeneous across groups. The CABF and Welch's t-tests assume data are normally or log-normally distributed and variances don't differ dramatically across groups (these tests account for some differences between variances). The Wilcoxon rank sum and Kruskal-Wallis tests assume that the distributions of the two groups are similar (though undetermined).

Interval Method

Statistical interval methods commonly applied in groundwater data analysis are the confidence interval, prediction interval, and tolerance interval. Prediction and tolerance intervals are often applied for compliance sampling events in Detection, Assessment, Phase I, and Phase II monitoring programs and for establishing background-based, groundwater protection standards, since only one initial sample per well is required during the compliance period. Confidence intervals are often applied for comparisons to a groundwater protection standard which is based on a mean or median value.

For all interval methods, the facility should check the normality or log-normality of the background dataset and the percentage of non-detects in the background dataset. If the background dataset is normally or log-normally distributed, and there are less than 50% non-detects, then a parametric interval can be calculated. If a distribution cannot be established for the background dataset or 50% or more of the data are non-detects, the facility should apply a non-parametric statistical limit.

Suggested sample sizes for the parametric and non-parametric versions of the above interval methods are provided in the attached table. Please note that these methods can lead to a higher false positive rate or lower statistical power with a smaller sample size. However, a statistical analysis can be conducted with a smaller dataset than the suggested size at any time.

It is the responsibility of the facility to collect an adequate number of background samples for the proposed statistical interval methods prior to the statistical analysis event required by the VSWMR. False positive and false negative rates associated with confidence, prediction and tolerance intervals must be protective of human health and the environment. If the facility chooses to apply a false positive rate of less than .01, the facility must include in the report a demonstration that a lower false positive rate will provide adequate statistical power to detect a release from the facility. Adequate statistical power is the ability to detect a three standard deviation increase above the mean with 50% power and a four standard deviation increase above the mean with 80% power.

Control Charts

The Shewhart-CUSUM control chart can be applied as an intra-well statistical test method. Please note that a variance from inter-well statistical comparisons must be granted by the VADEQ prior to applying an intra-well only monitoring program. Details of how to apply Shewhart-CUSUM control charts can be found in EPA 1992 (section 7). Please note that the background dataset can be updated every two years if there is no indication of an impact from the facility (increasing trend or significant result). The facility should leave a two-year time window between the background dataset and the compliance event to ensure that data associated with a slow release from the facility are not incorporated into the background dataset.

Other Methods

In the event the facility has selected any other method listed in the Virginia Solid Waste Management Regulations, the facility will collect the appropriate number of samples and shall maintain an appropriate level of significance mentioned above. If the facility prefers to apply a statistical method that is not in listed in the VSWMR, the facility must receive approval from the VADEQ prior to applying the test method.

Comparison of Compliance Well Data To A Standard During Assessment Or Corrective Action Monitoring

In accordance with sections 9 VAC 20-80-300.B.3 and 300.C.4? (VSWMR) the compliance data shall be compared to the groundwater protection standard (GWPS) if down gradient well concentrations exceed established background concentrations for Table 5.1 constituents. If a maximum contaminant level (MCL) is promulgated or alternate concentration limit (ACL) is established for a constituent, and the ACL or MCL is greater than the background limit (or statistically determined background level), the ACL or MCL is the ground-water protection standard. All new concentrations in the assessment or corrective action wells should be compared to the standard (i.e., ACL or MCL) using the lower normal confidence limit computed from at least four sampling values collected during the compliance period. The level of confidence of the interval should be 80% for a sample size of 4-7, and 90% for a sample size of 8-10 to ensure that the comparison has adequate power to detect an exceedance above the groundwater protection standard.

If the groundwater protection standard for a constituent is based on background data and exceeds the MCL or ACL, then the individual point of compliance measurements will be compared to the background limit and not the MCL or ACL.

However, for a particular sampling event, if the established groundwater protection standard is less than the VADEQ accepted quantitation limit (QL) then the QL becomes the standard for that sampling event, and the compliance well data will be compared to the QL.

G. VERIFICATION SAMPLING

The principal advantage of taking a verification sample is to maintain an acceptable site-wide false positive rate while the statistical test has adequate power to detect a release from the facility if it occurs. A verification sampling strategy involves collection of a pre-planned number of additional samples. A facility may choose to apply verification samples as follows:
The 1-of-m approach was initially suggested by Davis and McNichols (1987). The facility can take as many as m samples during the compliance period of the initial sampling event and if the 1-of-m (usually m=1 to 3) sample is below a prediction or tolerance limit, the constituent is said to have "passed" the test at that well. If the facility chooses to apply the verification sampling strategy, the alpha value should be modified as following:

a. Select a default value for a = 0.01
$$a = 0.01$$
b. Pass the first or one of one verification resamples, adjust alpha
$$a = (1 - .95^{\frac{1}{k}})^{\frac{1}{2}}$$
c. Pass the first or one of two verification resamples, adjust alpha
$$a = (1 - .95^{\frac{1}{k}})^{\frac{1}{3}}$$
d. Pass the first or two of two verification resamples, adjust alpha
$$a = \sqrt{1 - 0.95^{\frac{1}{k}}}\sqrt{\frac{1}{2}}$$

Where k is the number of comparisons and a is the site-wide false positive rate. Please note that alpha can not be less than 0.01 unless the facility shows that the statistical comparison has at least as much statistical power as the EPA reference power curves (EPA 1992, Appendix B). Since the verification sampling is pre-planned, the facility can adjust the upper statistical limit calculated for background to account for the fact that the verification samples will be collected. Please note that the regulations do not allow a facility to disregard the statistical evaluation in a situation when the facility is unable to collect a verification sample. Therefore, if the facility would like to take a verification sample, it should be taken during the compliance period of the initial sampling event and the statistical result must include the verification sample prior to submitting it to the VADEQ. The verification sample must be independent from the initial sample.

For questions or comments, please contact:
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Approved by: ______

Director
Office of Waste Technical Suopport

Date: 3/25/08

Note: This doccument has been reviewed by Waste Division staff.

TABLE 1
SUGGESTED MINIMUM BACKGROUND SAMPLES

	Parametric	Non-parametric	Non-parametric Interval % Confidence
CABF/Welch's T-test	4	NA	NA
Wilcoxon Rank Sum	NA	5	NA
Confidence Interval	4	NA	NA
Tolerance Interval	8	19	95%
Prediction Interval	8	13	99%#
Shewhart CUSUM Chart+	8	NA	NA

* The above tests can be used with fewer samples, however it will increase the false positive rate.
\# Includes one verification re-sample, use 19 samples for a 95% Prediction Interval with no verification resamples.
\+ For Intra-well testing only.
NA Not Applicable.

United States Environmental Protection Agency

ProUCL Version 5.1.002 Technical Guide

Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations

RESEARCH AND DEVELOPMENT

EPA/600/R-07/041
October 2015
www.epa.gov

ProUCL Version 5.1.002 Technical Guide

Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations

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NOTICE

The United States Environmental Protection Agency (U.S. EPA) through its Office of Research and Development (ORD) funded and managed the research described in this ProUCL Technical Guide. It has been peer reviewed by the U.S. EPA and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation by the U.S. EPA for use.

- All versions of the ProUCL software including the current version ProUCL 5.1 have been developed by Lockheed Martin, IS&GS - CIVIL under the Scientific, Engineering, Response and Analytical Services contract with the U.S. EPA and is made available through the U.S. EPA Technical Support Center (TSC) in Atlanta, Georgia (GA).

- Use of any portion of ProUCL that does not comply with the ProUCL Technical Guide is not recommended.

- ProUCL contains embedded licensed software. Any modification of the ProUCL source code may violate the embedded licensed software agreements and is expressly forbidden.

- ProUCL software provided by the EPA was scanned with McAfee VirusScan version 4.5.1 SP1 and is certified free of viruses.

With respect to ProUCL distributed software and documentation, neither the U.S. EPA nor any of their employees, assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed. Furthermore, software and documentation are supplied "as-is" without guarantee or warranty, expressed or implied, including without limitation, any warranty of merchantability or fitness for a specific purpose.

ProUCL software is a statistical software package providing statistical methods described in various U.S. EPA guidance documents. ProUCL does not describe U.S. EPA policies and should not be considered to represent U.S. EPA policies.

Minimum Hardware Requirements

ProUCL 5.1 will function but will run slowly and page a lot.

- Intel Pentium 1.0 gigahertz (GHz)
- 45 MB of hard drive space
- 512 MB of memory (RAM)
- CD-ROM drive or internet connection
- Windows XP (with SP3), Vista (with SP1 or later), or Windows 7.

ProUCL 5.1 will function but some titles and some Graphical User Interfaces (GUIs) will need to be scrolled. Definition without color will be marginal.

- 800 by 600 Pixels
- Basic Color is preferred

Preferred Hardware Requirements

- 1 GHz or faster Processor.
- 1 gigabyte (GB) of memory (RAM)
- 1024 by 768 Pixels or greater color display

Software Requirements

ProUCL 5.1 has been developed in the Microsoft .NET Framework 4.0 using the C# programming language. To properly run ProUCL 5.1 software, the computer using the program must have the .NET Framework 4.0 pre-installed. The downloadable .NET Framework 4.0 files can be obtained from one of the following websites:

- http://msdn.microsoft.com/netframework/downloads/updates/default.aspx
  http://www.microsoft.com/en-us/download/details.aspx?id=17851
  Quicker site for 32 Bit Operating systems

- http://www.microsoft.com/en-us/download/details.aspx?id=24872
  Use this site if you have a 64 Bit operating system

Installation Instructions when Downloading ProUCL 5.1 from the EPA Web Site

- Download the file SETUP.EXE from the EPA Web site and save to a temporary location.

- Run the SETUP.EXE program. This will create a ProUCL directory and two folders: 1) The TECHNICAL GUIDE (this document), and 2) DATA (example data sets).

- To run the program, use Windows Explorer to locate the ProUCL application file, and Double click on it, or use the RUN command from the start menu to locate the ProUCL.exe file, and run ProUCL.exe.

- To uninstall the program, use Windows Explorer to locate and delete the ProUCL folder.

Caution: If you have previous versions of the ProUCL, which were installed on your computer, you should remove or rename the directory in which earlier ProUCL versions are currently located.

Installation Instructions when Copying ProUCL 5.1 from a CD

- Create a folder named **ProUCL 5.1** on a local hard drive of the machine you wish to install ProUCL 5.1.

- Extract the zipped file **ProUCL.zip** to the folder you have just created.

- Run **ProUCL.exe**.

Note: If you have extension turned off, the program will show with the name **ProUCL** in your directory and have an Icon with the label **ProUCL**.

Creating a Shortcut for ProUCL 5.1 on Desktop

- To create a shortcut of the ProUCL program on your desktop, go to your ProUCL directory and right click on the executable program and send it to desktop. A ProUCL icon will be displayed on your desktop. This shortcut will point to the ProUCL directory consisting of all files required to execute ProUCL 5.1.

Caution: Because all files in your ProUCL directory are needed to execute the ProUCL software, one needs to generate a shortcut using the process described above. Simply dragging the ProUCL executable file from Window Explorer onto your desktop **will not work successfully** (an error message will appear) as all files needed to run the software are not available on your desktop. Your shortcut should point to the directory path with all required ProUCL files. All ProUCL files should reside in **one directory** on your computer (**and not on your Network System**) and your shortcut should point to that directory.

ProUCL 5.1

Software ProUCL version 5.1.002 (ProUCL 5.1), its earlier versions: ProUCL version 3.00.01, 4.00.02, 4.00.04, 4.00.05, 4.1.00, 4.1.01, and ProUCL 5.0.00, associated Facts Sheet, User Guides and Technical Guides (e.g., EPA 2010a, 2010b, 2013a, 2013b) can be downloaded from the following EPA website:

http://www.epa.gov/osp/hstl/tsc/software.htm
http://www.epa.gov/osp/hstl/tsc/softwaredocs.htm

Material for ProUCL webinars offered in March 2011, and relevant literature used in the development of various ProUCL versions can also be downloaded from the above EPA website.

Contact Information for all Versions of ProUCL

Since 1999, the ProUCL software has been developed under the direction of the Technical Support Center (TSC). As of November 2007, the direction of the TSC is transferred from Brian Schumacher to Felicia Barnett. Therefore, any comments or questions concerning all versions of ProUCL software should be addressed to:

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EXECUTIVE SUMMARY

The main objective of the ProUCL software funded by the United States Environmental Protection Agency (EPA) is to compute rigorous statistics to help decision makers and project teams in making good decisions at a polluted site which are cost-effective, and protective of human health and the environment. The ProUCL software is based upon the philosophy that rigorous statistical methods can be used to compute reliable estimates of population parameters and decision making statistics including: the upper confidence limit (UCL) of the mean, the upper tolerance limit (UTL), and the upper prediction limit (UPL) to help decision makers and project teams in making correct decisions. A few commonly used text book type methods (e.g., Central Limit Theorem [CLT], Student's t-UCL) alone cannot address all scenarios and situations occurring in environmental studies. Since many environmental decisions are based upon a 95 percent (%) UCL (UCL95) of the population mean, it is important to compute UCLs of practical merit. The use and applicability of a statistical method (e.g., student's t-UCL, CLT-UCL, adjusted gamma-UCL, Chebyshev UCL, bootstrap-t UCL) depend upon data size, data skewness, and data distribution. ProUCL computes decision statistics using several parametric and nonparametric methods covering a wide-range of data variability, distribution, skewness, and sample size. It is anticipated that the availability of the statistical methods in the ProUCL software covering a wide range of environmental data sets will help the decision makers in making more informative and correct decisions at Superfund and Resource Conservation and Recovery Act (RCRA) sites.

It is noted that for moderately skewed to highly skewed environmental data sets, UCLs based on the CLT and the Student's t-statistic fail to provide the desired coverage (e.g., 0.95) to the population mean even when the sample sizes are as large as 100 or more. The sample size requirements associated with the CLT increases with skewness. It would be incorrect to state that a CLT or Student's statistic based UCLs are adequate to estimate Exposure Point Concentrations (EPC) terms based upon skewed data sets. These facts have been described in the published documents (Singh, Singh, and Engelhardt [1997, 1999]; Singh, Singh, and Iaci 2002; and Singh *et al.* 2006) summarizing simulation experiments conducted on positively skewed data sets to evaluate the performances of the various UCL computation methods. The use of a parametric lognormal distribution on a lognormally distributed data set yields unstable impractically large UCLs values, especially when the standard deviation (*sd*) of the log-transformed data becomes greater than 1.0 and the data set is of small size less than (<) 30-50. Many environmental data sets can be modeled by a gamma as well as a lognormal distribution. The use of a gamma distribution on gamma distributed data sets tends to yield UCL values of practical merit. Therefore, the use of gamma distribution based decision statistics such as UCLs, UPLs, and UTLs should not be dismissed by stating that it is easier to use a lognormal model to compute these upper limits.

The suggestions made in ProUCL are based upon the extensive experience of the developers in environmental statistical methods, published environmental literature, and procedures described in many EPA guidance documents. These suggestions are made to help the users in selecting the most appropriate UCL to estimate the EPC term which is routinely used in exposure assessment and risk management studies of the USEPA. The suggestions are based upon the findings of many simulation studies described in Singh, Singh, and Engelhardt (1997, 1999); Singh, Singh, and Iaci (2002); and Singh *et al.* (2006). It should be pointed out that a typical simulation study does not (cannot) cover all real world data sets of various sizes and skewness from all distributions. When deemed necessary, the user may want to consult a statistician to select an appropriate upper limit to estimate the EPC term and other environmental parameters of interest. For an analyte (data set) with skewness (*sd* of logged data) near the end points of the skewness intervals presented in decision tables of Chapter 2 (e.g., Tables 2-9 through 2-11), the user may select the most appropriate UCL based upon the site conceptual site model (CSM), expert site knowledge, toxicity of the analyte, and exposure risks associated with that analyte.

The inclusion of outliers in the computation of the various decision statistics tends to yield inflated values of those decision statistics, which can lead to poor decisions. Often statistics that are computed for a data set which includes a few outliers tend to be inflated and represent those outliers rather than representing the main dominant population of interest (e.g., reference area). Identification of outliers, observations coming from population(s) other than the main dominant population is suggested, before computing the decision statistics needed to address project objectives. The project team may want to perform the statistical evaluations twice, once with outliers and once without outliers. This exercise will help the project team in computing reliable and defensible decision statistics which are needed to make cleanup and remediation decisions at polluted sites.

The initial development during 1999-2000 and all subsequent upgrades and enhancements of the ProUCL software have been funded by U.S. EPA through its Office of Research and Development (ORD). Initially ProUCL was developed as a research tool for U.S. EPA scientists and researchers of the Technical Support Center (TSC) and ORD- National Exposure Research Laboratory (NERL), Las Vegas. Background evaluations, groundwater (GW) monitoring, exposure and risk management and cleanup decisions in support of the Comprehensive Environmental Recovery, Compensation, and Liability Act (CERCLA) and RCRA site projects of the U.S. EPA are often derived based upon test statistics such as the Shapiro-Wilk (S-W) test, t-test, Wilcoxon-Mann-Whitney (WMW) test, analysis of variance (ANOVA), and Mann-Kendall (MK) test and decision statistics including UCLs of the mean, UPLs, and UTLs. To address the statistical needs of the environmental projects of the USEPA, over the years ProUCL software has been upgraded and enhanced to include many graphical tools and statistical methods described in many EPA guidance documents including: EPA 1989a, 1989b, 1991, 1992a, 1992b, 2000 Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), 2002a, 2002b, 2002c, 2006a, 2006b, and 2009. Several statistically rigorous methods (e.g., for data sets with nondetects [NDs]) not easily available in the existing guidance documents and in the environmental literature are also available in ProUCL 5.0/ProUCL 5.1.

ProUCL 5.1/ProUCL 5.0 has graphical, estimation, and hypotheses testing methods for uncensored-full data sets and for left-censored data sets including ND observations with multiple detection limits (DLs) or reporting limits (RLs). In addition to computing general statistics, ProUCL 5.1 has goodness-of-fit (GOF) tests for normal, lognormal and gamma distributions, and parametric and nonparametric methods including bootstrap methods for skewed data sets for computation of decision making statistics such as UCLs of the mean (EPA 2002a), percentiles, UPLs for a pre-specified number of future observations (e.g., k with k=1, 2, 3,...), UPLs for mean of future k ($\geq$1) observations, and UTLs (e.g., EPA 1992b, 2002b, and 2009). Many positively skewed environmental data sets can be modeled by a lognormal as well as a gamma model. It is well-known that for moderately skewed to highly skewed data sets, the use of a lognormal distribution tends to yield inflated and unrealistically large values of the decision statistics especially when the sample size is small (e.g., <20-30). For gamma distributed skewed uncensored and left-censored data sets, ProUCL software computes decision statistics including UCLs, percentiles, UPLs for future k ($\geq$1) observations, UTLs, and upper simultaneous limits (USLs).

For data sets with NDs, ProUCL has several estimation methods including the Kaplan-Meier (KM) method, regression on order statistics (ROS) methods and substitution methods (e.g., replacing NDs by DL, DL/2). ProUCL 5.1 can be used to compute upper limits which adjust for data skewness; specifically, for skewed data sets, ProUCL computes upper limits using KM estimates in gamma (lognormal) UCL and UTL equations provided the detected observations in the left-censored data set follow a gamma (lognormal) distribution. Some poor performing commonly used and cited methods such as the DL/2 substitution method and H-statistic based UCL computation method have been retained in ProUCL 5.1 for historical reasons, and research and comparison purposes.

The **Sample Sizes** module of ProUCL can be used to develop data quality objectives (DQOs) based sampling designs and to perform power evaluations needed to address statistical issues associated with a variety of site projects. ProUCL provides user-friendly options to enter the desired values for the decision parameters such as Type I and Type II error rates, and other DQOs used to determine the minimum sample sizes needed to address project objectives. The **Sample Sizes** module can compute DQO-based minimum sample sizes needed: to estimate the population mean; to perform single and two-sample hypotheses testing approaches; and in acceptance sampling to accept or reject a batch of discrete items such as a lot of drums containing hazardous waste. Both parametric (e.g., t-test) and nonparametric (e.g., Sign test, WMW test, test for proportions) sample size determination methods are available in ProUCL.

ProUCL has exploratory graphical methods for both uncensored data sets and for left-censored data sets consisting of ND observations. Graphical methods in ProUCL include histograms, multiple quantile-quantile (Q-Q) plots, and side-by-side box plots. The use of graphical displays provides additional insight about the information contained in a data set that may not otherwise be revealed by the use of estimates (e.g., 95% upper limits) and test statistics (e.g., two-sample t-test, WMW test). In addition to providing information about the data distributions (e.g., normal or gamma), Q-Q plots are also useful in identifying outliers and the presence of mixture populations (e.g., data from several populations) potentially present in a data set. Side-by-side box plots and multiple Q-Q plots are useful to visually compare two or more data sets, such as: site-versus-background concentrations, surface-versus-subsurface concentrations, and constituent concentrations of several GW monitoring wells (MWs). ProUCL also has a couple of classical outlier test procedures, such as the Dixon test and the Rosner test which can be used on uncensored data sets as well as on left-censored data sets containing ND observations.

ProUCL has parametric and nonparametric single-sample and two-sample hypotheses testing approaches for uncensored as well as left-censored data sets. Single-sample hypotheses tests: Student's t-test, Sign test, Wilcoxon Signed Rank test, and the Proportion test are used to compare site mean/median concentrations (or some other threshold such as an upper percentile) with some average cleanup standard, C_s (or a not-to-exceed compliance limit, A_0) to verify the attainment of cleanup levels (EPA 1989a; MARSSIM/EPA 2000; EPA 2006a) at remediated site areas of concern. Single-sample tests such as the Sign test and Proportion test, and upper limits including UTLs and UPLs are also used to perform intra-well comparisons. Several two-sample hypotheses tests as described in EPA guidance documents (e.g., 2002b, 2006b, 2009) are also available in the ProUCL software. The two-sample hypotheses testing approaches in ProUCL include: Student's t-test, WMW test, Gehan test and Tarone-Ware (T-W) test. The two-sample tests are used to compare concentrations of two populations such as site versus background, surface versus subsurface soils, and upgradient versus downgradient wells.

The **Oneway ANOVA** module in ProUCL has both classical and nonparametric Kruskal-Wallis (K-W) tests. Oneway ANOVA is used to compare means (or medians) of multiple groups such as comparing mean concentrations of areas of concern and to perform inter-well comparisons. In GW monitoring applications, the ordinary least squares (OLS) regression model, trend tests, and time series plots are used to identify upwards or downwards trends potentially present in constituent concentrations identified in wells over a certain period of time. The **Trend Analysis** module performs the M-K trend test and Theil-Sen (T-S) trend test on data sets with missing values; and generates trend graphs displaying a parametric OLS regression line and nonparametric T-S trend line. The **Time Series Plots** option can be used to compare multiple time-series data sets.

The use of the incremental sampling methodology (ISM) has been recommended by the Interstate Technology and Regulatory Council (ITRC 2012) for collecting ISM soil samples to compute mean concentrations of the decision units (DUs) and sampling units (SUs) requiring characterization and remediation activities. At many polluted sites, a large amount of discrete onsite and/or offsite background data are already available which cannot be directly compared with newly collected ISM data. In order to provide a tool to compare the existing discrete background data with actual field onsite or background ISM data, a Monte Carlo Background Incremental Sample Simulator (BISS) module was incorporated in ProUCL 5.0 and retained in ProUCL 5.1 (currently blocked from general use) which may be used on a large existing discrete background data set. The BISS module simulates incremental sampling methodology based equivalent background incremental samples. The availability of a large discrete background data set collected from areas with geological conditions comparable to the DU(s) of interest is a pre-requisite for successful application of this module. For now, the BISS module has been blocked for use as this module is awaiting adequate guidance and instructions for its intended use on discrete background data sets.

ProUCL software is a user-friendly freeware package providing statistical and graphical tools needed to address statistical issues described in many U.S. EPA guidance documents. ProUCL 5.0/ProUCL 5.1 can process many constituents (variables) simultaneously to: perform statistical tests (e.g., ANOVA and trend test statistics) and compute decision statistics including UCLs of mean, UPLs, and UTLs – a capability not available in several commercial software packages such as Minitab 16 and NADA for R (Helsel 2013). ProUCL also has the capability of processing data by group variables. Significant efforts have been made to make the software as user friendly as possible. For example, on the various GOF graphical displays, output sheets for GOF tests, OLS and ANOVA, in addition to critical values and/or *p*-values, the conclusion derived based upon those values is also displayed. ProUCL is easy to use and does not require any programming skills as needed when using commercial software packages and programs written in R.

Methods incorporated in ProUCL have been tested and verified extensively by the developers, researchers, scientists, and users. The results obtained by ProUCL are in agreement with the results obtained by using other software packages including Minitab, SAS®, and programs written in R Script. ProUCL 5.0/ProUCL 5.1 computes decision statistics (e.g., UPL, UTL) based upon the KM method in a straight forward manner without flipping the data and re-flipping the computed statistics for left-censored data sets; these operations are not easy for a typical user to understand and perform. This can become unnecessarily tedious when computing decision statistics for multiple variables/analytes. Moreover, unlike survival analysis, it is important to compute an accurate estimate of the *sd* which is needed to compute decision making statistics including UPLs and UTLs. For left-censored data sets, ProUCL computes a KM estimate of *sd* directly. These issues are elaborated by examples discussed in this User Guide and in the accompanying ProUCL 5.1 Technical Guide.

ProUCL does not represent a policy software of the government. ProUCL has been developed on limited resources, and it does provide many statistical methods often used in environmental applications. The objective of the freely available user-friendly software, ProUCL is to provide statistical and graphical tools to address environmental issues of environmental site projects for all *users* including those users who cannot or may not want to program and/or do not have access to commercial software packages. Some users have criticized ProUCL and pointed out some deficiencies such as: it does not have geostatistical methods; it does not perform simulations; and does not offer programming interface for automation. Due to the limited scope of ProUCL, advanced methods have not been incorporated in ProUCL. For methods not available in ProUCL, users can use other statistical software packages such as SAS® (available to EPA personnel) and R script to address their computational needs. Contributions from scientists and researchers to enhance methods incorporated in ProUCL will be very much appreciated. Just like other government documents (e.g., U.S. EPA 2009), various versions of ProUCL (2007, 2009, 2011, 2013, 2016) also make some rule-of thumb type suggestions (e.g., minimum sample size requirement of 8-10) based upon professional judgment and experience of the developers. It is recommended that the users/project team/agencies make their own determinations about the rule-of-thumb type suggestions made in ProUCL before applying a statistical method.

APPENDIX 7

VARIANCE:
ALTERNATE GROUNDWATER PROTECTION STANDARDS

Douglas W. Domenech
Secretary of Natural Resources

Lynchburg Office
7705 Timberlake Road
Lynchburg, Virginia 24502
(434) 582-5120
Fax (434) 582-5125

COMMONWEALTH of VIRGINIA

DEPARTMENT OF ENVIRONMENTAL QUALITY
BLUE RIDGE REGIONAL OFFICE
www.deq.virginia.gov

David K. Paylor
Director

Robert J. Weld
Regional Director

Roanoke Office
3019 Peters Creek Road
Roanoke, Virginia 24019
(540) 562-6700
Fax (540) 562-6725

November 2, 2010

Mr. John Petchul
Greif Packaging LLC
P. O. Box 339
Amherst, VA 24521

RE: Greif Packaging Industrial Landfill, Permit 536
ACL Variance Petition Final Approval

Dear Mr. Petchul:

Please accept this as a response to your petition for the use of Alternate Concentration Limits as groundwater protection standards (GPS) as allowed by 9 VAC 20-80-760.A. The 30-day public comment period ended on October 28, 2010 and no adverse public comments were received by the Department. The facility requested new or revised background based GPS for cadmium, chromium, cobalt, and vanadium during the comment period. The Department has approved the requested values and has modified the attached GPS table accordingly. Consistent with 9 VAC 20-80-790.B.3.(e), the Department hereby notifies you of the decision to approve the variance subject to the conditions outlined in the attached document. Please note that you will be responsible for meeting the conditions of the approval, as well as obtaining any other permits or authorizations that may be needed as a result of this approval.

As provided by Rule 2A:2 of the Supreme Court of Virginia, you have 30 days from the date of service of this decision to initiate an appeal of this decision, by filing notice with:

David K. Paylor, Director
Virginia Department of Environmental Quality
Waste Division
P.O. Box 1105
Richmond, Virginia 23218-1105

In the event that this decision is served to you by mail, three days are added to that period. Part Two of the rules of the Supreme Court of Virginia describes the required content of the Notice of Appeal, including specification of the Circuit Court to which an appeal is taken, and additional requirements governing appeals from decisions of administrative agencies.

Please contact me at (434) 582-6233 or via email at michael.sexton@deq.virginia.gov if you have any other questions.

Sincerely,

Michael D. Sexton

Michael D. Sexton
Groundwater Remediation Specialist

Attachments:

- Final Variance document
- Final GPS Table

cc: SW GW File – SWP 536
Aziz Farahmand, DEQ-BRRO (Roanoke)
Geoff Christe, DEQ-CO
Jeff Norman, Draper Aden Associates (Richmond)

Transmittal Attachment - 1

Variance to the Virginia Solid Waste Management Regulations

Use of Alternate Concentration Limits as Groundwater Protection Standards

In response to a Petition for Variance, submitted by Greif Packaging LLC for its landfill, Permit 536, as allowed under 9 VAC 20-80-760.A, the Director hereby grants approval limited to the conditions outlined below:

1] The approval is for the use of Alternate Concentration Limits (ACLs) as groundwater protection standards for the 157 constituents listed below which lack background data, or a USEPA Maximum Concentration Level (MCL):

1) Acenaphthene, 2) Acenaphthylene, 3) Acetone, 4) Acetonitrile / Methyl cyanide, 5) Acetophenone, 6) 2-Acetylaminofluorene / 2-AAF, 7) Acrolein, 8) Acrylonitrile, 9) Aldrin, 10) Allyl chloride 11) 4-Aminobiphenyl, 12) Anthracene, 13) Benzo[a]anthracene, 14) Benzo[b]fluoranthene 15) Benzo[k]flouranthene, 16) Benzo[ghi]perylene, 17) Benzyl alcohol, 18) BHC-alpha 19) BHC-beta, 20) BHC-delta, 21) Bis(2-chlorethoxy)methane, 22) Bis(2-chloroethyl)ether / Dichloroethyl ether, 23) Bis(2-chloro-1-methylethyl)ether / 2,2-Dichlorodiisopropyl ether, 24) Bromochloromethane / Chlorobromomethane, 25) 4-Bromophenyl phenyl ether 26) Butyl benzl phthalate / Benzyl butyl phthalate, 27) Carbon disulfide, 28) p-Chloroaniline / 4-Chloroaniline, 29) Chlorobenzilate, 30) p-Chloro-m-cresol / 4-Chloro-3-methylphenol, 31) Chloroethane / Ethyl chloride, 32) 2-Chloronaphthalene, 33) 2-Chlorophenol, 34) 4-Chlorophenyl phenyl ether, 35) Chloroprene, 36) Chrysene, ~~37) Cobalt~~, 38) Copper, 39) m-Cresol / 3-Methylphenol, 40) o-Cresol / 2-Methylphenol, 41) p-Cresol / 4-Methylphenol, 42) 4, 4-DDD, 43) 4,4-DDE, 44) 4,4-DDT, 45) Diallate 46) Dibenz[a,h]anthracene, 47) Dibenzofuran, 48) Di-n-butyl phthalate, 49) m-Dichlorobenzene / 1,3-Dichlorobenzene, 50) 3,3-Dichlorobenzidine, 51) Trans-1,4-Dichloro-2-butene, 52) Dichlorodifluoromethane / CFC-12 53) 1,1-Dichloroethane / Ethylidene chloride, 54) 2,4-Dichlorophenol, 55) 2,6-Dichlorophenol 56) 1,3-Dichloropropane / Trimethylene dichloride, 57) 2,2-Dichloropropane / Isopropylidene chloride 58) 1,1-Dichloropropene, 59) Cis-1,3-Dichloropropene, 60) Trans-1,3-Dichloropropene 61) Dieldrin, 62) Diethyl phthalate, 63) 0,0-Diethyl 0-2-pyrazinyl phosphorothioate / Thionazin 64) Dimethoate, 65) p-(Dimethylamino)azobenzene / Azobenzene, 66) 7,12-Dimethylbenzidine[a]anthracene, 67) 3,3-Dimethylbenzidine, 68) 2,4-Dimethylphenol / m-Xyenol, 69) Dimethyl phthalate, 70) m-Dinitrobenzene 71) 4,6-Dinitro-o-cresol / 4,6-Dinitro-2-methylphenol, 72) 2,4-Dinitrophenol, 73) 2,4-Dinitrotoluene, 74) 2,6-Dinitrotoluene, 75) Di-n-octyl phthalate, 76) Diphenylamine, 77) Disulfoton, 78) Endosulfan I, 79) Endosulfan II, 80) Endosulfan sulfate, 81) Endrin aldehyde, 82) Ethyl methacrylate, 83) Ethyl methanesulfonate, 84) Famphur, 85) Flouranthene, 86) Fluorene, 87) Hexachlorobutadiene, 88) Hexachloroethane, 89) Hexachloropropene, 90) 2-Hexanone / Methyl butyl ketone, 91) Isobutyl alcohol / Isobutanol, 92) Isodrin, 93) Isophrone, 94) Isosafrole, 95) Kepone, 96) Lead, 97) Methacrylonitrile, 98) Methapyrilene, 99) Methyl bromide / Bromomethane, 100) Methyl Chloride / Chloromethane, 101) 3-Methylcholanthrene, 102) Methyl Ethyl Ketone / MEK / 2-Butanone, 103) Methyl iodide / Iodomethane, 104) Methyl methacrylate, 105) Methyl methanesulfonate, 106) 2 Methylnaphthalene, 107) Methyl parathion / Parathion methyl, 108) 4-Methyl-2-pentanone / Methyl isobutyl ketone, 109) Methylene bromide, 110) Naphthalene, 111) 1,4-Naphthoquinone, 112) 1-Naphthylamine, 113) 2-Naphthylamine, 114) Nickel 115) o-Nitroaniline / 2-Nitroaniline, 116) m-Nitroaniline / 3-Nitroaniline, 117) p-Nitroaniline / 4-Nitroaniline, 118) Nitrobenzene, 119) o-Nitrophenol / 2-Nitrophenol, 120) p-Nitrophenol / 4-Nitrophenol, 121) N-Nitrosodi-n-butylamine, 122) N-Nitrosodiethylamine, 123) N-Nitrosodimethylamine, 124) N-Nitrosodiphenylamine, 125) N-Nitrosodipropylamine / Di-n-propylnitrosamine, 126) N-Nitrosomethylethylamine, 127) N-Nitrosopiperidine, 128) N-Nitrosopyrrolidine, 129) 5-Nitro-o-toludidine, 130) Parathion, 131) Pentachlorobenzene, 132) Pentachloronitobenzene, 133) Phenacetin, 134) Phenanthrene, 135) Phenol, 136) p-Phenylenediamine, 137) Phorate, 138) Pronamide, 139) Propionitrile / Ethyl cyanide, 140) Pyrene, 141) Safrole, 142) Silver, 143) Sulfide, 144) 1,2,4,5-Tetrachlorobenzene, 145) 1,1,1,2-Tetrachloroethane, 146) 1,1,2,2-Tetrachloroethane, 147) 2,3,4,6-Tetrachlorophenol, 148) Tin, 149) o-Toluidine / 2-Methylaniline, 150) Trichlorofluoromethane / CFC-11, 151) 2,4,5-Trichlorophenol, 152) 2,4,6-Trichlorophenol, 153) 2,4,5-Trichloro-phenoxyacetic acid, 154) 1,2,3-Trichloropropane, 155) O,O,O-Triethyl phosphorothioate, 156) (syn) 1,3,5-Trinitrobenzene, ~~157) Vanadium~~, 158) Vinyl acetate, 159) Zinc

2] Establishment of an ACL for use as groundwater protection standards for any constituent not listed above will require the submittal and review of a separate Variance Petition.

3] If a Maximum Contaminant Level (MCL) is promulgated under Section 1412 of the Safe Drinking Water Act (Part 141, Title 40, Code of Federal Regulations) for any of the constituents listed above, the newly promulgated MCL will supercede the ACL as the groundwater protection standard, and approval for the use of the former ACL shall be withdrawn.

4] If a site-specific background concentration is proposed by the Permittee and approved for use by the Department, the newly approved background value will supercede the ACL as the groundwater protection standard, and approval for the use of the former ACL shall be withdrawn.

5] For those constituents listed above, when REAMS-based ACL concentration values change as a result of modifications to the risk data used by USEPA, the revised ACL concentration value shall immediately replace the outdated concentration value and the Permittee will not be required to go through the Variance process before implementing the revised value.

6] Nothing within this Variance shall restrict the Permittee from filing a Variance for use of revised ACL concentration values based on a system other than REAMS if he/she so chooses.

7] For those constituents listed above that have an ACL concentration value of zero, or have an ACL concentration value which is lower than the laboratory's Limit of Quantitation (LOQ), the LOQ shall act as the groundwater protection standard (GPS) for the purposes of performing statistical comparisons, only.

8] As allowed under 9 VAC 20-80-760.C.2.b.(1), with this approval, the Permittee acknowledges that the Director has the authority under the VSWMR to undertake a periodic review of the ACLs and such review will be undertaken on an annual basis.

If any of the conditions outlined above are violated in any form or manner, the consistent with 9 VAC 20-80-790.C.2, Director approval of this Variance shall be immediately terminated.

APPROVED: Jeffery A. Steers

Jeffery A. Steers
Director

DATE: 01 November 2010

Transmittal Attachment - 2

Groundwater Protection Standards with ACL's (1/27/09)

Facility Name: Greif Packaging Industrial Landfill Permit 536

Constituent (CAS RN)		*Concentration*		*Source*
Acenaphthene	83-32-9	134	µg/l	ACL
Acenaphthylene	208-96-8	(0)*	µg/l	ACL
Acetone	67-64-1	8750	µg/l	ACL
Acetonitrile	75-05-8	38	µg/l	ACL
Acetophenone	98-86-2	224	µg/l	ACL
2-Acetylaminofluorene / 2-AAF	53-96-3	(0)*	µg/l	ACL
Acrolein	107-02-8	0.015	µg/l	ACL
Acrylonitrile	107-13-1	0.037	µg/l	ACL
Aldrin	309-00-2	0.004	µg/l	ACL
Allyl chloride	107-05-1	0.639	µg/l	ACL
4-Aminobiphenyl	92-67-1	0.003	µg/l	ACL
Anthracene	120-12-7	671	µg/l	ACL
Antimony	**---**	**6**	**µg/l**	**MCL**
Arsenic	**---**	**10**	**µg/l**	**MCL**
Barium	**---**	**2,000**	**µg/l**	**MCL**
Benzene	**71-43-2**	**5**	**µg/l**	**MCL**
Benzo[a]anthracene	56-55-3	0.092	µg/l	ACL
Benzo[b]fluoranthene	205-99-2	0.092	µg/l	ACL
Benzo[k]fluoranthene	207-08-9	0.92	µg/l	ACL
Benzo[ghi]perylene	191-24-2	(0)*	µg/l	ACL
Benzo[a]pyrene	**50-32-8**	**0.2**	**µg/l**	**MCL**
Benzyl alcohol	100-51-6	7,825	µg/l	ACL
Beryllium	**---**	**4**	**µg/l**	**MCL**
BHC-alpha	319-84-6	0.011	µg/l	ACL
BHC-beta	319-85-7	0.037	µg/l	ACL
BHC-delta	319-86-8	(0)*	µg/l	ACL
BHC-gamma (Lindane)	**58-89-9**	**0.2**	**µg/l**	**MCL**
Bis(2-chloroethoxy)methane	111-91-1	47	µg/l	ACL
Bis(2-chloroethyl)ether / Dichloroethyl ether	111-44-4	0.009	µg/l	ACL
Bis(2-chloro-1-methylethyl)ether / 2,2-Dichlorodiisopropyl ether	108-60-1	0.26	µg/l	ACL
Bis(2-ethylhexyl)phthalate	**117-81-7**	**6**	**µg/l**	**MCL**
Bromochloromethane / Chlorobromomethane	74-97-5	(0)*	µg/l	ACL
Bromodichloromethane Bromoform Chloroform Dibromochloromethane *(trihalomethane group)**	**75-27-4 75-25-2 67-66-3 124-48-1**	**80**	**µg/l**	**MCL**
Bromoform / Tribromomethane				
4-Bromophenyl phenyl ether	101-55-3	(0)*	µg/l	ACL
Butyl benzyl phthalate / Benzyl butyl phthalate	85-68-7	35	µg/l	ACL
Cadmium	**---**	**11.1**	**µg/l**	**BKG**
Carbon disulfide	75-15-0	391	µg/l	ACL
Carbon tetrachloride	**56-23-5**	**5**	**µg/l**	**MCL**
Chlordane	**N/E**	**2**	**µg/l**	**MCL**
p-Chloroaniline / 4-Chloroaniline	106-47-8	1.24	µg/l	ACL
Chlorobenzene	**108-90-7**	**100**	**µg/l**	**MCL**
Chlorobenzilate	510-15-6	0.609	µg/l	ACL
p-Chloro-m-cresol / 4-Chloro-3-methylphenol	59-50-7	10,955	µg/l	ACL
Chloroethane / Ethyl chloride	75-00-3	1,293	µg/l	ACL
Chloroform / Trichloromethane				
2-Chloronaphthalene	91-58-7	179	µg/l	ACL
2-Chlorophenol	95-57-8	11	µg/l	ACL
4-Chlorophenyl phenyl ether	7005-72-3	(0)*	µg/l	ACL
Chloroprene	126-99-8	5.13	µg/l	ACL
Chromium	**---**	**127.67**	**µg/l**	**BKG**
Chrysene	218-01-9	9.2	µg/l	ACL
Cobalt	---	140.9	µg/l	BKG
Copper	---	626	µg/l	ACL

m-Cresol / 3-Methylphenol	108-39-4	783	µg/l	ACL
o-Cresol / 2-Methylphenol	95-48-7	783	µg/l	ACL
p-Cresol / 4-Methylphenol	106-44-5	78.3	µg/l	ACL
Cyanide	**57-12-5**	**200**	**µg/l**	**MCL**
2,4-D / 2,4-Dichlorophenoxyacetic acid	**94-75-7**	**70**	**µg/l**	**MCL**
4, 4-DDD	72-54-8	0.28	µg/l	ACL
4,4-DDE	72-55-9	0.197	µg/l	ACL
4,4-DDT	50-29-3	0.197	µg/l	ACL
Diallate	2303-16-4	1.1	µg/l	ACL
Dibenz[a,h]anthracene	53-70-3	0.009	µg/l	ACL
Dibenzofuran	132-64-9	(0)*	µg/l	ACL
Dibromochloromethane / Chlorodibromomethane				
1,2-Dibromo-3-chloropropane / DBCP	**96-12-8**	**0.2**	**µg/l**	**MCL**
1,2-Dibromoethane / Ethylene dibromide	**106-93-4**	**0.05**	**µg/l**	**MCL**
Di-n-butyl phthalate	84-74-2	1,565	µg/l	ACL
Di-n-octyl phthalate	117-84-0	313	µg/l	ACL
0-Dichlorobenzene / 1,2-Dichlorobenzene	**95-50-1**	**600**	**µg/l**	**MCL**
m-Dichlorobenzene / 1,3-Dichlorobenzene	541-73-1	(0)*	µg/l	ACL
p-Dichlorobenzene / 1,4-Dichlorobenzene	**106-46-7**	**75**	**µg/l**	**MCL**
3,3-Dichlorobenzidine	91-94-1	0.15	µg/l	ACL
Trans-1,4-Dichloro-2-butene	110-57-6	(0)*	µg/l	ACL
Dichlorodifluoromethane / CFC-12	75-71-8	142	µg/l	ACL
1,1-Dichloroethane / Ethylidene chloride	75-34-3	1.9	µg/l	ACL
1,2-Dichloroethane / Ethylene dichloride	**107-06-2**	**5**	**µg/l**	**MCL**
1,1-Dichloroethylene / 1,1-Dichloroethene	**75-35-4**	**7**	**µg/l**	**MCL**
Cis-1,2-Dichloroethylene / Cis-1,2-Dichloroethene	**156-59-2**	**70**	**µg/l**	**MCL**
Trans-1,2-Dichloroethylene/Trans-1,2-Dichloroethene	**156-60-5**	**100**	**µg/l**	**MCL**
2,4-Dichlorophenol	120-83-2	47	µg/l	ACL
2,6-Dichlorophenol	87-65-0	(0)*	µg/l	ACL
1,2-Dichloropropane / Propylene dichloride	**78-87-5**	**5**	**µg/l**	**MCL**
1,3-Dichloropropane / Trimethylene dichloride	142-28-9	45	µg/l	ACL
2,2-Dichloropropane / Isopropylidene chloride	594-20-7	(0)*	µg/l	ACL
1,1-Dichloropropene	563-58-6	(0)*	µg/l	ACL
Cis-1,3-Dichloropropene	10061-01-5	(0)*	µg/l	ACL
Trans-1,3-Dichloropropene	10061-02-6	(0)*	µg/l	ACL
Dieldrin	60-57-1	0.004	µg/l	ACL
Diethyl phthalate	84-66-2	12,520	µg/l	ACL
0,0-Diethyl 0-2-pyrazinyl phosphorothioate / Thionazin	297-97-2	(0)*	µg/l	ACL
Dimethoate	60-51-5	3.13	µg/l	ACL
p-(Dimethylamino)azobenzene / Azobenzene	60-11-7	0.015	µg/l	ACL
7,12-Dimethylbenz [a] anthracene	57-97-6	0.0003	µg/l	ACL
3,3-Dimethylbenzidine	119-93-7	0.006	µg/l	ACL
2,4-Dimethylphenol / m-Xyenol	105-67-9	313	µg/l	ACL
Dimethyl phthalate	131-11-3	(0)*	µg/l	ACL
m-Dinitrobenzene	99-65-0	1.565	µg/l	ACL
4,6-Dinitro-o-cresol / 4,6-Dinitro-2-methylphenol	534-52-1	1.565	µg/l	ACL
2,4-Dinitrophenol	51-28-5	31.3	µg/l	ACL
2,4-Dinitrotoluene	121-14-2	31.3	µg/l	ACL
2,6-Dinitrotoluene	606-20-2	15.65	µg/l	ACL
2-sec-Butyl-4,6-dinitrophenol / Dinoseb	**88-85-7**	**7**	**µg/l**	**MCL**
Diphenylamine	122-39-4	391	µg/l	ACL
Disulfoton	298-04-4	0.63	µg/l	ACL
Endosulfan I	959-96-8	(0)*	µg/l	ACL
Endosulfan II	33213-65-9	(0)*	µg/l	ACL
Endosulfan sulfate	1031-07-8	(0)*	µg/l	ACL
Endrin	**72-20-8**	**2**	**µg/l**	**MCL**
Endrin aldehyde	7421-93-4	(0)*	µg/l	ACL

Ethylbenzene	**100-41-4**	**700**	**µg/l**	**MCL**
Ethyl methacrylate	97-63-2	201	µg/l	ACL
Ethyl methanesulfonate	62-50-0	(0)*	µg/l	ACL
Famphur	52-85-7	(0)*	µg/l	ACL
Fluoranthene	206-44-0	626	µg/l	ACL
Fluorene	86-73-7	89	µg/l	ACL
Heptachlor	**76-44-8**	**0.4**	**µg/l**	**MCL**
Heptachlor epoxide	**1024-57-3**	**0.2**	**µg/l**	**MCL**
Hexachlorobenzene	**118-74-1**	**1**	**µg/l**	**MCL**
Hexachlorobutadiene	87-68-3	0.86	µg/l	ACL
Hexachlorocyclopentadiene	**77-47-4**	**50**	**µg/l**	**MCL**
Hexachloroethane	67-72-1	4.784	µg/l	ACL
Hexachloropropene	1888-71-7	(0)*	µg/l	ACL
2-Hexanone / Methyl butyl ketone	591-78-6	(0)*	µg/l	ACL
Indeno [1,2,3-cd] pyrene	193-39-5	0.09	µg/l	ACL
Isobutyl alcohol / Isobutanol	78-83-1	671	µg/l	ACL
Isodrin	465-73-6	(0)*	µg/l	ACL
Isophorone	78-59-1	70.5	µg/l	ACL
Isosafrole	120-58-1	(0)*	µg/l	ACL
Kepone	143-50-0	0.004	µg/l	ACL
Lead	---	15	µg/l	MCL[a]
Mercury (inorganic)	**---**	**2**	**µg/l**	**MCL**
Methacrylonitrile	126-98-7	0.39	µg/l	ACL
Methapyrilene	91-80-5	(0)*	µg/l	ACL
Methoxychlor	**72-43-5**	**40**	**µg/l**	**MCL**
Methyl Bromide / Bromomethane	74-83-9	3.18	µg/l	ACL
Methyl Chloride / Chloromethane	74-87-3	1.43	µg/l	ACL
3-Methylcholanthrene	56-49-5	0.003	µg/l	ACL
Methylene bromide	74-95-3	22.36	µg/l	ACL
Methylene chloride	**75-09-2**	**5**	**µg/l**	**MCL**
Methyl Ethyl Ketone / MEK / 2-Butanone	78-93-3	2,667	µg/l	ACL
Methyl iodide / Iodomethane	74-88-4	(0)*	µg/l	ACL
Methyl methacrylate	80-62-6	3.73	µg/l	ACL
Methyl methanesulfonate	66-27-3	0.676	µg/l	ACL
2 Methylnaphthalene	91-57-6	8.94	µg/l	ACL
Methyl parathion / Parathion methyl	298-00-0	3.9	µg/l	ACL
4-Methyl-2-pentanone / Methyl isobutyl ketone	108-10-1	802	µg/l	ACL
Naphthalene	91-20-3	0.09	µg/l	ACL
1,4-Naphthoquinone	130-15-4	(0)*	µg/l	ACL
1-Naphthylamine	134-32-7	(0)*	µg/l	ACL
2-Naphthylamine	91-59-8	0.037	µg/l	ACL
Nickel	---	313	µg/l	ACL
o-Nitroaniline / 2-Nitroaniline	88-74-4	(0)*	µg/l	ACL
m-Nitroaniline / 3-Nitroaniline	99-09-2	3.19	µg/l	ACL
p-Nitroaniline / 4-Nitroaniline	100-01-6	3.19	µg/l	ACL
Nitrobenzene	98-95-3	1.25	µg/l	ACL
o-Nitrophenol / 2-Nitrophenol	88-75-5	(0)*	µg/l	ACL
p-Nitrophenol / 4-Nitrophenol	100-02-7	(0)*	µg/l	ACL
N-Nitrosodi-n-butylamine	924-16-3	0.002	µg/l	ACL
N-Nitrosodiethylamine	55-18-5	0.0004	µg/l	ACL
N-Nitrosodimethylamine	62-75-9	0.001	µg/l	ACL
N-Nitrosodiphenylamine	86-30-6	13.7	µg/l	ACL
N-Nitrosodipropylamine / Di-n-propylnitrosamine	621-64-7	0.01	µg/l	ACL
N-Nitrosomethylethylamine	10595-95-6	0.003	µg/l	ACL
N-Nitrosopiperidine	100-75-4	0.007	µg/l	ACL
N-Nitrosopyrrolidine	930-55-2	0.032	µg/l	ACL
5-Nitro-o-toluidine	99-55-8	2.03	µg/l	ACL
Parathion	56-38-2	93.9	µg/l	ACL
Polychlorinated biphenyls / PCB's	**---**	**0.5**	**µg/l**	**MCL**
Pentachlorobenzene	608-93-5	12.5	µg/l	ACL
Pentachloronitrobenzene	82-68-8	0.26	µg/l	ACL
Pentachlorophenol	**87-86-5**	**1**	**µg/l**	**MCL**
Phenacetin	62-44-2	30	µg/l	ACL
Phenanthrene	85-01-8	(0)*	µg/l	ACL
Phenol	108-95-2	4,695	µg/l	ACL
p-Phenylenediamine	106-50-3	2,974	µg/l	ACL

Phorate	298-02-2	3.13	µg/l	ACL
Pronamide	23950-58-5	1,173	µg/l	ACL
Propionitrile / Ethyl cyanide	107-12-0	(0)*	µg/l	ACL
Pyrene	129-00-0	67	µg/l	ACL
Safrole	94-59-7	0.304	µg/l	ACL
Selenium	**---**	**50**	**µg/l**	**MCL**
Silver	---	78	µg/l	ACL
Silvex / 2,4,5-TP	**93-72-1**	**50**	**µg/l**	**MCL**
Styrene	**100-42-5**	**100**	**µg/l**	**MCL**
Sulfide	18496-25-8	(0)*	µg/l	ACL
1,2,4,5-Tetrachlorobenzene	95-94-3	4.7	µg/l	ACL
1,1,1,2-Tetrachloroethane	630-20-6	0.407	µg/l	ACL
1,1,2,2-Tetrachloroethane	79-34-5	0.052	µg/l	ACL
Tetrachloroethylene / PCE	**127-18-4**	**5**	**µg/l**	**MCL**
2,3,4,6-Tetrachlorophenol	58-90-2	470	µg/l	ACL
Thallium	**---**	**2**	**µg/l**	**MCL**
Tin	---	9,390	µg/l	ACL
Toluene	**108-88-3**	**1,000**	**µg/l**	**MCL**
o-Toluidine / 2-Methylaniline	95-53-4	0.37	µg/l	ACL
Toxaphene	**N/E**	**3**	**µg/l**	**MCL**
1,2,4-Trichlorobenzene	**120-82-1**	**70**	**µg/l**	**MCL**
1,1,1-Trichloroethane / Methylchloroform	**71-55-6**	**200**	**µg/l**	**MCL**
1,1,2-Trichloroethane	**79-00-5**	**5**	**µg/l**	**MCL**
Trichloroethylene / Trichloroethene	**79-01-6**	**5**	**µg/l**	**MCL**
Trichlorofluoromethane / CFC-11	75-69-4	470	µg/l	ACL
2,4,5-Trichlorophenol	95-95-4	1,565	µg/l	ACL
2,4,6-Trichlorophenol	88-06-2	6.09	µg/l	ACL
2,4,5-Trichloro-phenoxyacetic acid	93-76-5	157	µg/l	ACL
1,2,3-Trichloropropane	96-18-4	0.009	µg/l	ACL
O,O,O-Triethyl phosphorothioate	126-68-1	(0)*	µg/l	ACL
1,3,5-Trinitrobenzene	99-35-4	470	µg/l	ACL
Vanadium	---	442	µg/l	BKG
Vinyl acetate	108-05-4	148	µg/l	ACL
Vinyl chloride / Chloroethene	**75-01-4**	**2**	**µg/l**	**MCL**
Xylene (total)	**N/E**	**10,000**	**µg/l**	**MCL**
Zinc	---	4,695	µg/l	ACL

<table>
<tr><th colspan="5">End Notes</th></tr>
<tr><td colspan="5">MCL >USEPA Maximum Contaminant Level, represents Federal standards set for drinking water. Most MCLs are treatment-technology based.</td></tr>
<tr><td colspan="5">MCL[a] > USEPA MCL "action level" (non-risk based), used as ACL for Lead only.</td></tr>
<tr><td colspan="5">If a revised MCL is promulgated by EPA for any constituent on this listing, the new MCL shall immediately be adopted as the groundwater protection standard.</td></tr>
<tr><td colspan="5">ACL > Alternate Concentration Limits (risk-based). In those cases where the ACL value is found to be less than the laboratory Limit of Quantitation (LOQ) for the constituent, the LOQ shall serve as the "ACL" for statistical comparison purposes. This is generally to constituents with ACLs less than 2ppb.</td></tr>
<tr><td colspan="5">For facilities which obtained an approved ACL variance in May 2007 or later, when REAMS-based ACL's are revised based on new EPA health/risk criteria, those ACL's shall immediately be adopted for use as the groundwater protection standard (GPS) in this table.</td></tr>
<tr><td colspan="5">For facilities which desire to use non REAMS-based ACL values, the use of those ACL's must be approved via the Variance procedure outlined in the VSWMR.</td></tr>
<tr><td colspan="5">BKG > Site specific background concentration data, as approved by DEQ.</td></tr>
<tr><td colspan="5">Mg/l > micrograms per liter (parts per billion).</td></tr>
<tr><td colspan="5">(0)* > Indicates those constituents which have no established ACL. In cases such as these, the laboratory Limit of Quantitation (LOQ) for the constituent shall serve as the "ACL" for statistical comparison purposes.</td></tr>
<tr><td colspan="5">CAS RN > Chemical Abstracts Service Registry Number.</td></tr>
<tr><td colspan="5">Shaded Rows (if any) denote those groundwater constituents for which Groundwater Protection Standards are set as MCLs and MCLs supersede any available ACL.</td></tr>
<tr><td colspan="5">The MCL for the Trihalomethane group is a cumulative number of 80 ppb, for one or all of the constituents.</td></tr>
<tr><td>A GPS exceedance is triggered for a sampling event when there is a statistical exceedance of:</td><td>1) an MCL, if applicable</td><td>2) an ACL, if applicable</td><td>3) site specific background, if applicable</td><td>4) the lab LOQ, when MCL, BKG, or ACL is unavailable</td></tr>
</table>

COMMONWEALTH of VIRGINIA

Molly Joseph Ward
Secretary of Natural Resources

DEPARTMENT OF ENVIRONMENTAL QUALITY
Blue Ridge Regional Office
3019 Peters Creek Road, Roanoke, Virginia 24019
(540) 562-6700; Fax (540) 562-6725
www.deq.virginia.gov

David K. Paylor
Director

Robert J. Weld
Regional Director

June 1, 2017

Mr. Todd Asselborn
Greif Packaging LLC
P. O. Box 339
Amherst, VA 24521

Re: Proposed Background Based Groundwater Protection Standard (GPS)
Greif Packaging Industrial Landfill, SWP 536

Dear Mr. Asselborn:

The Department has completed a review of the background based groundwater standards (GPS) presented in the facility's proposal dated February 15, 2017. This demonstration was submitted on behalf of the Company by Draper Aden Associates and asserts that a site-specific background level is an appropriate GPS for antimony.

Pursuant to the Virginia Solid Waste Management Regulations (VSWMR) 9 VAC 20-81.250.A.6.b.(3), the facility may request to use facility background concentration, if the facility background concentration is higher than the maximum contaminant level (MCL) or other health-based level used to determine the GPS, if approved by the director. After review of the information contained in the submission, the Company's proposal to utilize a background based GPS is approved for antimony. The GPS value to be used is 18.8 ug/l. Please refer to the attached statistical memo dated May 25, 2017 for additional information. The approved GPS should be placed in the facility's operating record (i.e., update the current GPS table taking into account the new background value and place the new table in the operating record).

The information in this letter is based solely on materials supplied by the Permittee or their environmental representative. The resulting review of those materials was undertaken with respect to applicable portions of the VSWMR and/or EPA guidance. This letter does not make or imply a final determination of compliance with the VSWMR, nor does it constitute a final case decision regarding any of the groundwater actions undertaken at the above-listed solid waste facility.

If you should have any further questions, please do not hesitate to contact Mr. Michael Sexton by phone at 434-582-6233 or by e-mail michael.sexton@deq.virginia.gov, for further assistance.

Sincerely,

EALohman

Elizabeth A. Lohman
Land Protection Program Manager

Enclosure: DEQ Statistical Memo dated May 25, 2017

cc: Michael Sexton, DEQ-BRRO
Doug Foran, DEQ-BRRO
Hasan Keceli, DEQ-CO
Jeff Norman, Draper Aden Associates (Richmond)
ECM - SWP 536

DEQ
Department of Environmental Quality

OFFICE OF FINANCIAL RESPONSIBILTY AND WASTE PROGRAMS

MEMO

TO: Michael Sexton

THOUGH: Sanjay Thirunagari

FROM: Hasan Keceli H.K

DATE: May 25, 2017

CC: Geoff Christe

SUBJECT: Review of Proposed Groundwater Protection Standard for Greif Packaging Industrial Landfill, Permit # 536

I have reviewed the proposed groundwater protection standard for the Greif Packaging Industrial Landfill.

Based on the information provided in the report and my review, the proposed groundwater protection standard for antimony is acceptable. If the facility has any questions, I can be reached at (804) 698-4246.